Astronomy

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Sky and TELESCOPE

In This Issue:

The Crab Nebula

Sailing the Seven Seas

Relativity . . .

The Student Observatory at R. P. I.

The Starry Heavens in October

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Vol. 1, No. 12

OCTOBER, 1942

20 cents

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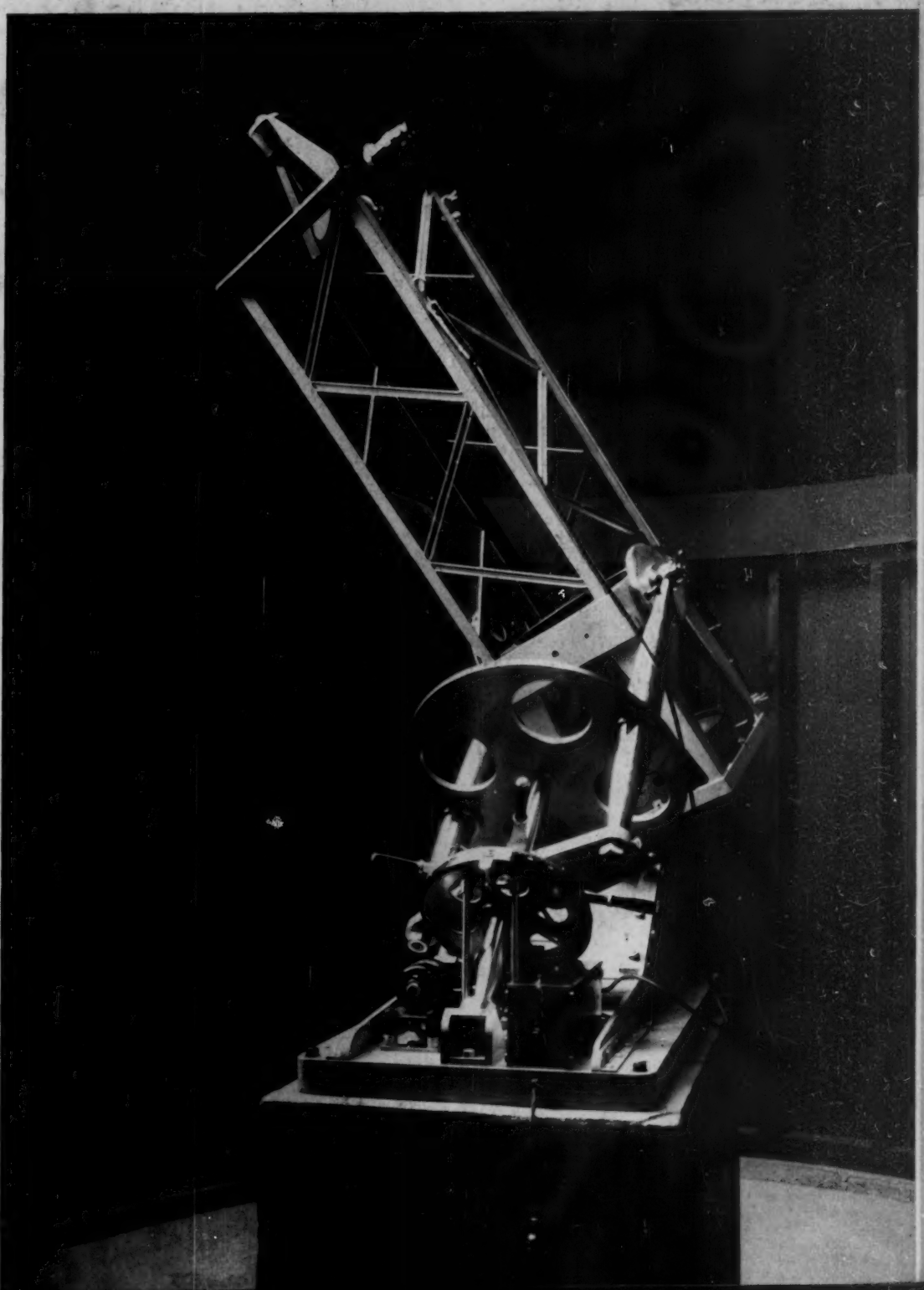

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The Editors Note . . .

PERHAPS no scientific subject has stirred public interest more than relativity. At times such interest has become a fervor, as in the case of the "Einstein riot" at the American Museum of Natural History on January 8, 1930, when thousands of persons stormed a meeting of the Amateur Astronomers Association to see a movie on simple relativity. Of course, this "mob" had no idea of whether or not it would understand the film, but its collective heart hoped it might.

So it is with all of us. We hear that relativity has changed our world, and we want to know how this has come about. We hope to visualize curved space, the fourth dimension, and other concepts usually associated with relativity. But there is always something lacking—we never seem able to throw off the fetters of the Newtonian universe in which we were brought up.

But we also know that just as Newton's once revolutionary ideas eventually became high school textbook material, so Einstein's relativity will some day be the basis of the universe conceived by the man in the street. So we go to relativity films, we hear lectures and read books. Amateur astronomers, in particular, want to know how Einstein has changed astronomy, the science in which gravitation has long been the dominant idea.

In this issue appears the first in a series of articles by Dr. Philipp Frank, now at Harvard, but formerly occupying the chair of theoretical physics at Prague University, where he was Albert Einstein's successor for 26 years. We invite you to a simple intellectual feast, as Dr. Frank presents new concepts in an unusually comprehensible fashion.

No reader of this periodical should avoid or fail to follow Dr. Frank's series, but we warn you: take time, rethink each thought, discuss it with others, refer frequently to physics and astronomy textbooks, and be sure to digest the first installment thoroughly because it lays the groundwork for those to come.

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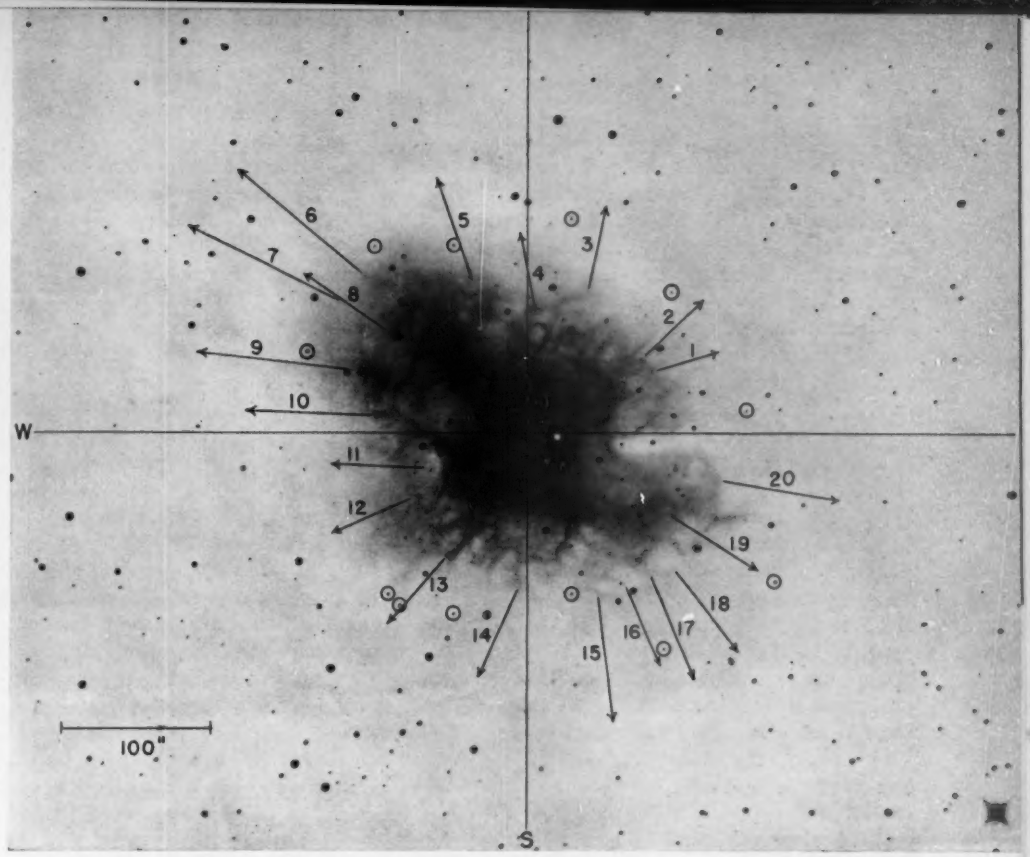


Fig. 1. On a negative print of the Crab nebula, the author has shown by vectors the expansion for the next 500 years, if it continues at the present rate. Comparison stars are encircled. Engraving, courtesy the "Astrophysical Journal."

THE CRAB NEBULA

BY JOHN C. DUNCAN, *Wellesley College*

THE Crab nebula has revealed its story to modern astronomers in the manner of the great epic poets, who began their stories in the middle.

This unique little nebula is No. 1952 in Dreyer's *New General Catalogue,* where the numbers are assigned in the order of right ascension, but in Messier's famous catalogue it has the distinction of being No. 1. The garrulous Admiral William Henry Smyth, in his *Cycle of Celestial Objects* (published in 1844), says, "This fine nebula is remarkable as having been discovered by M. Messier—the comet-ferret of Louis XV—while observing ζ Tauri and a comet in 1758, when he caught up a 'whitish light, elongated like the flame of a taper.' This accident induced him to form his well-known and useful *Catalogue* of nebulae and clusters, from the observations of himself, Lacaille, and Méchain, in order to prevent astronomers from mistaking any of these objects for comets; and the List of 103 which he furnished to the public was considered to have scraped them all together, as far as climate permitted." However, Messier was not the first to notice Messier 1; in a note to his catalogue there occurs the phrase "observée par le Docteur Bevis vers 1731"—probably John Bevis (1695-1771), London physician and amateur astronomer, known to Edmond Halley.

A small telescope shows no more than Messier's description conveys, and the early drawings made at large telescopes bear little resemblance to the nebula as it is revealed by modern instruments, either visual or photographic. Perhaps the best description is that by C. O. Lampland[1], who says, "It is an object of complex structure, roughly an ovate nebulous mass, having at first sight the appearance of a coarsely and rudely woven fabric shot through with loose-spun, threadlike filaments, giving it a peculiar frayed or raveled aspect along its border.... The longer axis of the nebula lies in position angle 120° and the dimensions, to the outlying parts of the filaments, are roughly 4′ x 5′.5." (The extreme dimension of the filamentous structure, measured on recent photographs, is 356″.) Near the center is a double star with nearly equal components of about the 16th magnitude, 5″ apart in position angle 200°. The nebula is classed by H. D. Curtis[2] as a planetary, but with the remark: "It is not a typical planetary in form, and it is doubtful whether it is properly to be included as a member of the class." Ritchey used to compare it to the filamentous Veil nebula in Cygnus (N.G.C. 6992) as that beautiful object might appear if seen endwise. The Crab nebula, however, appears so unlike any other actually observed object as to defy definite classification.

Evidence of activity in this nebula was first obtained in 1913, when V. M. Slipher photographed its spectrum and found it to be continuous, except that the principal nebular emission lines appeared faintly, and that each of these lines was split in two. Its study by direct photography with the 40-inch Lowell reflector was at once undertaken by Lampland, who announced[1] in 1921 that changes—either motion or local brightening or fading—had taken place in the brighter, amorphous parts, mainly in the region northwest of the central double star.

To verify Lampland's discovery, the present writer photographed the nebula in April, 1921, with the 60-inch Mt. Wilson reflector and compared the plate with an excellent one made by G. W. Ritchey with the same instrument in October, 1909. The comparison, made with a blink microscope, revealed changes such as Lampland had announced and, what was more exciting, showed in many of the outer filaments and nebular condensations an unmistakable outward motion constituting an expansion of the nebula[3]. Seventeen years later, this result was confirmed and extended by a comparison of Ritchey's plate with one made in 1938[4].

The measured displacement of 20 nebular features is illustrated in Figure 1, in which vectors drawn on a negative picture of the nebula represent the motion that, at the observed rate, will take place in the next 500 years. The rectangular axes in the diagram intersect at the image of the northeast component of the central double star. The white dot is situated centrally among the vectors, and the measured displacements suggest that, if the expansion has been at a uniform rate, the 20 nebulous condensations were gathered close to this point some 800 years ago. (The date derived by a least-squares solution is 1172 A.D.; but it is subject to uncertainty because it involves extrapolation based on the assumption of continued uniform motion over an interval more than 26 times the interval of observation, and because of the difficulty of making precise measures on such nebulous objects.)

That the center of the nebula is now obviously northwest of the radiant point suggests a northwestward proper motion of the nebula as a whole. The measures revealed a slow westward proper motion of the southwest component of the central double star but no motion in the northeast component, indicating that the double is an optical one, not a binary.

After these results were obtained but before they were published, a similar in-

vestigation was carried out by A. N. Deutsch and V. V. Lavdovsky[5] by comparing photographs made by them with the astrographic telescope at Poulkovo in February, 1939, and one made with the same instrument by S. K. Kostinsky in 1896. Their results and mine are in remarkably close agreement.

Meanwhile, the spectrum of the Crab nebula was not being neglected. Slipher's observation was confirmed by R. F. Sanford at Mt. Wilson in 1919; and in 1937 N. U. Mayall[6], at the Lick Observatory, obtained excellent spectrograms with the slit of his spectrograph placed along the major and minor axes of the nebula, which showed the bright lines double at the middle but with the components merging at their ends (Figure 2). This is obviously a Doppler effect of the expansion of the nebula; the violet component of each double line is emitted by the approaching front of the shell and the red component by the receding rear. The tips of the lines are emitted by atoms at the apparent edge, where the whole motion of expansion is across the line of sight. Mayall found a radial velocity of expansion of 1,300 kilometers per second which, together with the observed rate of angular expansion, indicates a distance of the nebula of about 4,000 light-years. The major axis is therefore about six light-years long.

Expansion on this gigantic scale implies a vast cataclysm such as only the novae are known to exemplify, and astronomers have long entertained the idea that the Crab nebula is an old nova. Knut Lundmark, E. P. Hubble, and especially Mayall[7] have discussed the probability that the outburst was that of a "guest star" recorded in Chinese and Japanese annals as having appeared in the region of ζ Tauri in 1054 A.D. (No record of this nova seems to have been preserved in Europe.) Yasuaka Iba quotes[8] from the diary of "the aristocrat, Sadaiye Fujiwara," that the nova of 1054 appeared in the region of ζ Tauri and was as bright as Jupiter. J. J. L. Duyvendak, professor of Chinese languages in the University of Leiden, has translated[9] pertinent data from various Chinese sources in which it is recorded that the guest star appeared on July 4, 1054, "several inches southeast of T'ien-kuan"* and after more than a year became invisible; that it was visible from July 4, 1054, to April 17, 1056; that it was of an iridescent yellow color; that it was visible by day, like Venus; that it was reddish-white; that it appeared in the Pleiades; that it shone like a comet; and that it was as large as Jupiter.

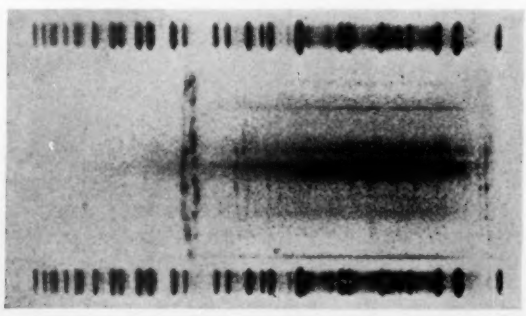
Notwithstanding the vague and contradictory character of these accounts, it is evident that a bright nova did appear somewhere near the present location of Messier 1 in the year 1054; and its identification as the parent of the Crab nebula is doubtless as well established as the identifications of some of the famous eclipses of ancient history or of the early observations of Halley's comet. Mayall and J. H. Oort[10], indeed, have concluded not only that the Crab nebula may be confidently identified with the nova of 1054, but that the latter was a supernova and probably one of the brightest on record (apparent magnitude −6.0, absolute magnitude −16.5, luminosity 350,000,000 times the sun's).

The probability that the Crab nebula represents a late stage in the history of a supernova has made it an especially inviting subject for further research, and so the most powerful instrumental equipment available has recently been turned upon it. Exceedingly interesting photographs have been made by Walter Baade[11] with the 100-inch Mt. Wilson telescope and with special plates and light filters. Those made in light ranging in wave length from λ3300 to λ6500 (Figure 3) resemble closely those made on ordinary plates. A photograph in the region λ5200 to λ6600 (thus including the red alpha line of hydrogen) shows the filaments more distinctly and suggests that the nebula consists of two concentric parts: an S-shaped, amorphous nebulosity, and a more extended, less flattened, elliptical shell of filaments. A plate exposed to light ranging from λ6300 to λ6700 (Figure 4) shows the filamentous portion almost alone, while one utilizing the extreme red and near infrared (λ7200 to λ8400, a region in which the spectrum of the nebula is continuous only, without perceptible bright lines) shows only the amorphous nebulosity (Figure 5).

On plates such as the one reproduced in Figure 4, the filaments are so clear and sharp that micrometer settings can be made upon them with considerable accuracy. This fact and the large scale of the 100-inch telescope will make possible, when such plates are duplicated after a sufficient interval of years, a more satisfactory investigation of the expansion of the nebula.

R. Minkowski[11] has recently studied the Crab nebula with a highly efficient spectrograph attached to the 60-inch telescope, placing the slit in carefully chosen positions on the nebular image, and has interpreted his spectrograms in the light of astrophysical theory. Emission lines appear wherever the slit crosses the image of a filament, whereas elsewhere the spectrum is continuous, showing that the amorphous nebulosity has a continuous spectrum only, and that the bright lines belong to the filamentous shell. The hydrogen lines are relatively weak, and the photograph shown in Figure 4 was made mainly in the light of two red lines of nitrogen II and one of sulphur II, Hα contributing but slightly. The continuous spectrum contains nearly

* Duyvendak translates T'ien-kuan as ζ Tauri, and a difficulty arises from the position of the Crab nebula, which is a little more than a degree *northwest* of that star. It is held, however, that T'ien-kuan designates not a definite star, but an asterism which includes ζ Tauri, but of whose center the exact position is now unknown.



Left: Spectrum with slit along the major axis; exposure, $5^h\ 50^m$. Below: Minor axis spectrum exposure, $6^h\ 15^m$. The absorption lines H and K (appearing white on the negative print) and the G band are from moonlight.

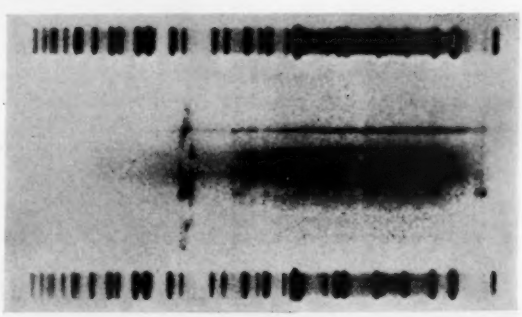
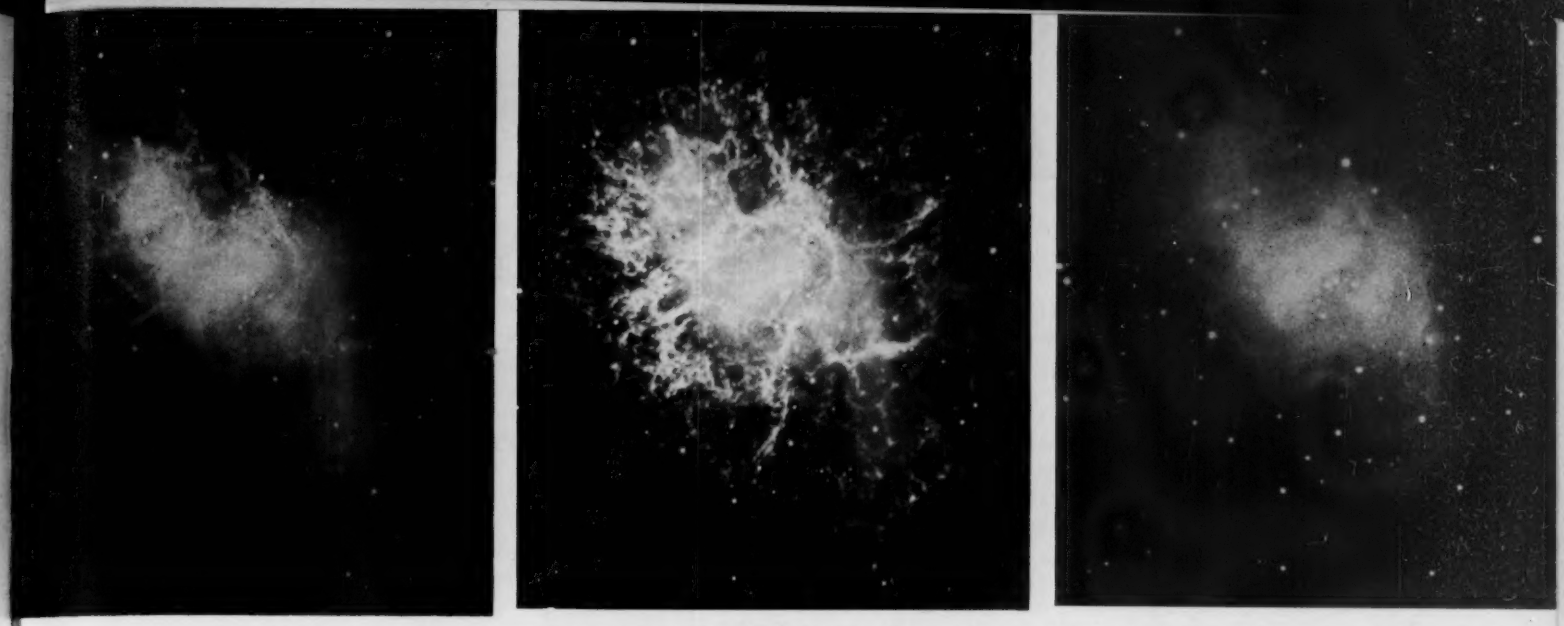


Fig. 2. The spectrum of the Crab nebula, photographed by N. U. Mayall. The direct photograph shows the major and minor axes of the nebula, along which the slit was placed. Engravings, courtesy Astronomical Society of the Pacific.



Figs. 3, 4, and 5 (left to right). Photographs of the Crab nebula, by W. Baade with the 100-inch Mt. Wilson telescope. Figure 3, in ordinary light, suggests the dual structure revealed so strikingly by Figure 4 (our back-cover plate this month) and Figure 5. Figure 4 is taken on an Eastman 103E plate, Schott RG2 filter, thus using only red light from 6300 to 6700 angstroms; Figure 5, Eastman IN plate, Wratten 88 filter—near infrared light, 7200 to 8400 angstroms.

all the light of the nebula and it shows no discontinuities, except a slight one at the limit of the Balmer series. Since the red and violet components of the emission lines, contributed by the front and back surfaces of the filamentous shell, are of practically equal intensity, the amorphous portion must be very nearly transparent and its light cannot be reflected or scattered starlight. Minkowski infers that its luminosity is due to transitions of free electrons in the rare gas of the nebula, that the electron density in the nebula is about 1,000 electrons per cubic centimeter, the electron temperature is about 50,000°, and the mass of the nebula about 15 times that of the sun.

Minkowski finds that, to bring about these conditions, the star which excites the nebula to luminosity must have an effective temperature of about 500,000°, a luminosity 30,000 times that of the sun, and a radius only 1/50 the sun's radius; and that it is now in the process of becoming a white dwarf. The evidently low hydrogen content supports recent theories which require the consumption of hydrogen to maintain a star's output of radiation until the white-dwarf stage is reached. The northeast component of the central double star (the stationary component) has a spectrum and a color index of approximate type G4, which rules it out as the exciting star of the nebula. The southwest component (the one with perceptible proper motion) has a color index of only 0.14 and an apparently perfectly continuous spectrum, and it is therefore strongly suspected of being the transformed nova.

The rate of expansion of the Crab nebula is so great that, within an astronomically brief interval, perhaps by 3000 A.D., the material of which it is composed must become so tenuous that it cannot perceptibly shine. It is very likely that the entire episode of the Chinese nova and its sequel, so far as it can be perceived from the earth, has taken place in an interval shorter than the 4,000 years required by its light to reach us. The story of the Crab nebula, therefore, may well have ended centuries before it seemed to begin, and in the interim was carried secretly by the light waves spreading in ever-increasing spheres from the place of the outburst.

———

[1] Pub. A.S.P. 33, 79, 1921.
[2] Lick Observatory Publications, 13, Plate X, Figure 11.
[3] Proc. Nat. Acad. Sci., 7, 179, 1921; Mt. W. Comm., No. 76.
[4] Ap. J. 89, 347, 1939; Mt. W. Contr., No. 609.
[5] Poulkovo Circular No. 30, 1940.
[6] Pub. A.S.P. 49, 101, 1937.
[7] A.S.P. Leaflet, No. 119, 1939; The Telescope, Sept.-Oct., 1939.
[8] Popular Astronomy, 42, 251, 1934.
[9] Pub. A.S.P. 54, 91, 1942.
[10] Pub. A.S.P. 54, 95, 1942.
[11] Ap. J. 96, 1942; Mt. W. Contr. 666.

DO YOU KNOW?

By L. J. Lafleur

I. Score five points for each question answered correctly, and one point for each question where you do not attempt to select the answer.

1. A true "black body" would have an albedo (reflecting power) of
   a. zero c. one
   b. one half d. minus one
2. The ratio of brightness between successive stellar magnitudes is about
   a. two c. five
   b. two and a half d. 10
3. One of the following is not the brightest star in its constellation:
   a. Alpha Corvi c. Alpha Ophiuchi
   b. Alpha Cygni d. Alpha Centauri
4. There is a 1st-magnitude star in
   a. Reticulum c. Gemini
   b. Pavo d. Corona Borealis
5. The ecliptic passes through
   a. Auriga c. Aquila
   b. Aries d. Vela
6. A "radiant point" occurs only when a number of objects
   a. reach the atmosphere at the same point
   b. are produced by an explosion
   c. move in parallel paths
   d. appear at the same distance
7. The interior of the earth is known to be
   a. gaseous c. viscous
   b. liquid d. elastic
8. To harness the tides for power, you would locate your plant
   a. in the middle of the ocean
   b. in the Bay of Fundy
   c. on the Florida east-coast beaches
   d. in the Great Lakes
9. Geocentric latitude, compared to geographic latitude
   a. is always greater b. is always less
   c. is sometimes more and sometimes less
   d. varies so their sum always equals 90 degrees
10. The aberration of light cannot be used to measure the
    a. size of the earth's orbit
    b. rotation of the earth
    c. speed of the earth in its orbit
    d. rotation of the galaxy

II. This is a question in relation and proportion. For example, one question might be "moon : earth : : Triton : ? " That would mean that the moon has the same relationship to the earth as Triton has to what? The answer is Neptune, since the moon is the satellite of the earth and Triton is the satellite of Neptune. Count five points for each correct answer, and two points for each partially correct answer (in which you have the right idea of the relationship).

1. azimuth : altitude : : right ascension : ?
2. Tycho (crater) : moon : : red spot : ?
3. degree : angle : : angstrom : ?
4. summer : Cancer : : autumn : ?
5. parallax : distance : : magnitude : ?
6. inferior planet : elongation : : superior planet : ?
7. Titan : Saturn : : Callisto : ?
8. Orion : Betelgeuse : : Gemini : ?
9. 2,000 A.D. : Polaris : : 3,000 B.C. : ?
10. eclipse of the moon : earth : : transit of Venus : ?

(Answers on page 20)

SAILING THE SEVEN SEAS

By William H. Barton, Jr.

From the history of navigation most of its fundamental problems can be learned, especially that of the determination of longitude. The links connecting old and new are discussed here and in the Hayden Planetarium this month.

IT is appropriate that in October, 1942, we should be writing about navigation and its history. Just 450 years ago this month, on the 12th, Columbus made his landfall on San Salvador.

Half a millenium ago navigation was not the art it is today. There were no optical instruments, no chronometers. There were no accurate charts, no methods for working any but the most elementary sights. Of course, there were no aids to navigation—radio was unknown by over 400 years, there was no hydrographic office, no coast guard. Variation in the magnetic compass was not understood nor charted. The entire art of finding one's way over the earth was in an elementary state.

But navigation was not new, by any means. Years earlier the Arabs had navigated their camel trains across the desert by taking sights on the sun at high noon. This is perhaps the most classic of all the problems in navigation. Even today finds the navigating officer, or perhaps "the old man" himself, on the bridge or deck shooting the sun with a sextant to find his latitude.

The stars were lighthouses in the sky to the early Polynesians. Their story is shrouded somewhat in mystery, but they sailed their great canoes over long distances and set their courses by the North Star. From their home port in Hawaii, about 20 degrees north of the equator, the Polynesians sailed down to Tahiti, nearly as far south of the equator. This 2,400-mile trip was really a remarkable one for that day and age.

Their navigators, specially trained in the sacred art, used a crude device that had in it an *artificial horizon* something like that in the modern bubble octant used in air navigation. On the home journey, finding latitude was the problem and here the Sacred Calabash played its part. The instrument was made from a gourd about three feet long. The bottom was spherical and the sides straight. Near the top a series of holes were made in a plane at right angles to the main axis of the gourd. They were at such a distance from the top edge that when the Calabash was held level, the water running from all the holes, sighting through one of them over the top edge would bring the pole star into view. That is—if the vessel were in the latitude of Hawaii.

On the journey south, the course was nearly a straight line, but on the return the Polynesians veered considerably to the eastward until the equator was crossed. They knew when this crossing occurred because only north of the "line" is Polaris in the sky. Then the Calabash came into use each night until the critical latitude was reached, when a sharp turn to the west led directly home.

One of the well-known principles of navigation is that the altitude of the pole in the sky is the latitude of the observer. It is true that the pole star is more than a degree from the actual pole, but in rough methods no refinements need be observed. Since a degree represents about 60 nautical miles, the Sacred Calabash might be that much in error. But for that day and age, such an error was not serious.

Even Columbus was not so good at celestial navigation. According to the best authorities, he did not practice it with any positive results while at sea, probably mostly because he lacked the necessary equipment. There are three separate ways of finding out where you are in a vessel at sea. The simplest (in principle, at least) is piloting. Next comes dead reckoning, and then celestial navigation. The second is tied in with the other two.

When near land, you usually have a chart on which the principal features of the land and of the ocean bottom (depths or soundings) are portrayed As long as you are in sight of land or can make soundings, you can get your "bearings"—the directions of particular points of land as you see them. From the crossings of these bearings you can *fix* your position on the chart. Then you determine the course and speed you want to maintain to get to another point on the chart. This is called piloting.

But once in the open sea there are no charted marks. A map of the ocean is merely a sheet of paper with lines of latitude and longitude ruled on it. And these, of course, are only figments of man's mind, not things to be seen or felt or run into by your vessel. However, if the navigator knows his direction of travel, his course, and the speed that he makes, he can plot his course on such a blank piece of paper (a *plotting sheet*). This course line will lead him from his known *point of departure* to a spot of latitude and longitude where he thinks he is. This position is his dead reckoning position. Wind, current, and poor steering may all affect his course, so he is practically sure *not* to be in the position he has plotted. This kind of navigation is called dead reckoning—a strange term which has a strange history.

In keeping track of a vessel's speed and course, the old-time navigator was able to deduce his position without benefit of celestial observations. This, then, became *deduced reckoning*, which was

It is a far cry from the fragile canoe of the Polynesians to the stately modern liner, in which the bridge is a world in itself, but both types of vessels must apply the same navigation principles. French Line photo.

JOHN HARRISON'S SEA WATCH.
The legends below read :—

DUPLICATE OF HARRISON'S TIMEKEEPER, made in 1767–9 by LARCUM KENDALL.	TIMEKEEPER (No. 4), made in 1755–9 by JOHN HARRISON, which won in 1764 the reward of £20,000 offered by the British Government in 1713.
Used by Capt. James Cook, R.N., 1772–5.	
" " " " 1776–9.	
" G. Vancouver 1791.	

These watches measure 5·2 inches over all. They are preserved at the Royal Observatory, Greenwich. This beautiful machine of Harrison's, justly the most noted of all time-keepers, was the forerunner of the marine chronometer upon which navigation is dependent.

Illustration and caption are from "Splendour of the Heavens."

abbreviated as *ded. reckoning*. This oft-repeated term, no doubt passed by word of mouth by those who had never seen it written (and probably could not read it if they had), became dead reckoning, as it is today.

The third method is celestial navigation or astro-navigation, as our British brothers call it. By means of observations on the heavenly bodies, the navigator can locate his vessel within a small error. Today, that art has been brought to a high state of perfection, but it is based on the fundamentals described in *Sky and Telescope* last month by Dr. Fletcher G. Watson, in the first of this series of articles on navigation.

The earth, you remember, is criss-crossed by a series of lines called parallels of latitude which run at right angles to another series called meridians of longitude. They form a grid by which a mariner can describe his position as well as a New Yorker can say he is at 42nd Street and 5th Avenue.

The meridians run from pole to pole, north and south, like the creases in a peeled orange. They mark longitude, which is measured east and west around the earth from an arbitrary spot. Various places have been used as the starting point. Hipparchus was probably the first to use the term for longitude and he made Rhodes, his home town, the zero point. The famous geographer, Ptolemy, decided upon the most westerly known place of his day, Insulae Fortunatae. When the voyages of discovery were in progress, Teneriffe was chosen.

In 1630, a scientific congress was called in Paris by Cardinal Richelieu. The decision of this learned body was in favor of the island of Ferro (one of the Canary Islands) as the starting place from which to mark longitude. That place received the authority of Louis XIII on April 25, 1634, and it was to supersede all others. But modern maps used either Paris or Greenwich. The Washington Meridian Congress in 1884 recommended the exclusive use of Greenwich. And there it stands today.

Longitude is closely associated with time. Since the sun goes around the earth (or appears to, at least, and appearances are what interest a navigator) in 24 hours, then each hour it crosses 15 degrees of longitude. Therefore, if you know what time it is where you are (apparent sun position east or west of your meridian) and at the same instant what time it is in Greenwich, longitude 0 degrees, the difference of the two times is the longitude of your position. For instance, when it is 2:00 p.m. in St. Louis, by the sun, it is six hours later. or 8:00 p.m. in Greenwich. St. Louis is 90 degrees, or six hours, west of Greenwich, as shown by this difference in apparent local time.

Now a ship in the Western Hemisphere may make this same observation. Its local time will be 2:00 p.m., and its Greenwich chronometer will show the time at Greenwich to be 8:00 p.m. Then the ship is six hours west of Greenwich, but if it were in the Mississippi River at St. Louis, it would hardly need celestial navigation to fix its position. But the same observation would apply to a ship in the Gulf of Mexico off New Orleans, or to one near the Galapagos Islands off western South America. In other words, this difference in time which denotes 90 degrees west longitude applies to a vessel or a locality anywhere along the 90th meridian of longitude.

But longitude was a hurdle Columbus could not jump, nor could his followers for nearly 300 years. Methods did come into use for observing local time by the sun, but that was only half the requirement. There was no way to tell the time anywhere else because there were no dependable timepieces.

Columbus depended upon the disinterested help of his "grummets," or cabin boys, to "turn the glass" and keep the time since he had sailed from port. Every half hour the sandglass had to be turned—and this is no doubt the origin of our system of ship's bells on the half hour even today. Turning the glass was a day and night job, in fair weather or foul. At best it was an inaccurate way of telling time, and the job was no doubt performed with more ritual than precision. No wonder Columbus mistook the West Indies for Japan!

Not until 1761 did John Harrison produce his first chronometer, thus enabling navigators to carry the time with them. This was really the start of the technique of modern navigating. About the same time, Hadley was developing his quadrant, the forerunner of the modern sextant. The era that followed "Longitude" Harrison brought into being improved tables for the positions of the heavenly bodies, better nautical almanacs, the establishment of national observatories to produce these almanacs and to keep the timepieces and sextants in repair and adjustment.

The Yankee stargazer, Nathaniel Bowditch, first published his *American Practical Navigator* in 1802. No better thumbnail biography of Bowditch and his "navigator's Bible" can be found than in the sketch at the front of the present edition (1938) published by the United States Hydrographic Office:

NATHANIEL BOWDITCH (1773-1838)

"Nathaniel Bowditch was born on March 26, 1773, at Salem, Mass. Circumstances

(Continued on page 15)

Gilbert Stuart's last portrait, unfinished at the time of his death, was of Nathaniel Bowditch. It is reproduced here.

Amateur Astronomers

THAT PERFECTLY BEAUTIFUL ECLIPSE

ALTHOUGH an eclipse of the moon may not have much scientific value as far as modern astronomers are concerned, it has a tremendous aesthetic appeal and an inspirational effect on those who watch it, as the eclipse of the night of August 25-26th proved.

Unlike its recent predecessors, this eclipse coincided with ideal weather conditions wherever it was visible. The letters and photographs which have come in from all parts of the country unite in saying that the sky was unusually transparent and that it was the best eclipse in years. Leland S. Copeland, who writes our "Starry Heavens" each month, reported from Santa Barbara: "Our usual high fog didn't roll in last night, so we saw the lunar eclipse."

Most remarked-on features seemed to be: the brilliance of the remaining crescent just before totality; the amount of light in the umbra; its redness; its lack of symmetry, so that the darkest part did not center on the moon until 10 minutes past mid-eclipse; a green color of the outer parts of the umbra; the "doughnut" moon at mid-totality; the darkness of one's surroundings during totality; the brilliance of the Milky Way during totality (even seen well from uptown New York, according to Arthur H. Rosenberg); the occultations of several stars in Aquarius during totality (visible only in telescopes); the three-dimensional effect produced by the shadow, making the moon seem quite spherical; meteors during totality; the brightness of the limb in the shadow, when the other was outside of it; the space given the eclipse by the press.

In this last matter, special attention should be drawn to the report in *The New Yorker* magazine for September 5th. This was written by a reporter who attended the eclipse party of the Amateur Astronomers Association of New York at Oceanside, Long Island. The reporter does not mention specifically the seven glasses of punch he had. Peter A. Leavens, whose photograph of the late phase appears here, was host to a score of the amateurs and several scores of onlookers. His night's work included lapsed-time color movies, and colored stills. So anxious was he to break the jinx of past cloudy eclipses that he spent $35. on insurance against a drop of rain witnessed by three people. Many of the other New York amateurs had telescopes arranged for lunar photography. George V. Plachy, secretary of the New York group, invites correspondence with other amateurs for exchange of information and photographs.

In his regular weekly column in the New York *Sun*, the veteran amateur, James C. Hickey, reports that several persons saw green shading in the umbra. His principal correspondent was amateur D. C. Wysor, of Ridgewood, N. J.:

"I did not notice this green band until the moon was nearing totality. . . it really stood out in marvelous beauty. I would not say that it was as dark a green as the darkest of the red was dark red, but it was unmistakable, nevertheless. Then I wondered why the green rays, which are supposed to be bent more than the red, should have appeared up toward the sunlight."

This green on the moon is "predicted" by Oscar E. Monnig, in the Texas Observers' *Bulletin* for August, when he suggests the observer try to see if the green appearance is objective or a contrast effect. Apparently it can be explained by the fact that the inner red of the umbra is *transmitted* and refracted through the atmosphere *close* to the earth's surface, other colors failing to get through; however, higher in the air, the yellows and greens are transmitted.

A complete report of the eclipse has been received from Dr. James C. Bartlett, of Baltimore, Md., portions of which will be abstracted next month, along with parts of other reports and letters received from the following, which are hereby acknowledged: C. E. Harris, Greenfield, Mass.; J. Robert Mantler, Flushing, N. Y.; Robert B. Eccleston, Binghamton, N. Y.; C. LeBaron Goeller, Endwell, N. Y.; Ladd Observatory, Brown University; Earl C. Witherspoon, Sumter, S. C.

AMATEUR ASTRONOMERS ASSOCIATION
(New York City)

Lectures: October 7th, Dr. Roy K. Marshall, Fels Planetarium—"Astronomy in the Service of Culture." October 21st, Dr. Lyman A. Spitzer, Yale University—"The Origin of the Solar System."

Classes: Elementary Astronomy; Advanced Astronomy; Mathematics Survey; Astronomical Photography; Meteorology; Appreciation of Astronomy; also, Optics and Telescope Making, conducted by the Optical Division. Write to the secretary, Hayden Planetarium, for full details of classes and membership in the society.

The moon in partial eclipse, 1:10 a.m., August 26th. Photo by Peter A. Leavens, with 4-inch camera of 10-foot focus, enlarged three times from original negative.

RELATIVITY . . .

and Its Astronomical Implications

By Philipp Frank, *Harvard University*

PART I

THE heroic period in the struggle for the laws governing the orbits of our planetary system was the period of three men: Copernicus, Galileo, Newton. To have a rough idea about the duration of that struggle, we may say that Copernicus worked around 1500, Galileo around 1600, and Newton around 1700. Copernicus laid the foundation to the *pattern of description* of those orbits which (with Kepler's corrections) are used by astronomers today.

However, the ambition of men like Galileo and Newton was a much deeper one than Copernicus'. They wanted to set up a pattern of description which covered not only the orbits of planets, but which would enable us to describe any motion in the universe, such as the motion of balls pushed by the direct impact of our muscle force or the motion of the particles which produce optical sensations. This general pattern of description was started by Galileo and reached its climax with Newton's "laws of motion."

In the period from Newton (around 1700) to Einstein (around 1900), these laws have never been seriously challenged. Einstein's work was the first radical progress beyond Galileo and Newton in the field of the general laws of motion. Observe that the period from Newton to Einstein was nearly as long as that from Copernicus to Newton—about two centuries each.

Einstein's laws of motion have the reputation of being much harder to understand than Newton's. This reputation results primarily from *underrating* the difficulties implied by the Newtonian laws. Two centuries of triumphs of those laws have produced the illusion that they are not merely physical hypotheses, but necessary results of reasonable thinking or of good sense. The first step toward understanding Einstein has to be, therefore, the destruction of a sort of complacency. If we succeed in understanding how sweeping and daring Newton's hypotheses have been, we are not likely to cherish the illusion that Newton's laws of motion have been the last word in the history of human knowledge. To understand Newton will set the green light for understanding Einstein.

1. The role of "inertia" and "force" in Newton's pattern of description

THE Galileo-Newton way to approach the phenomena of motion was to describe them by describing the accelerations of the moving bodies concerned. By *acceleration* we mean not only a change in speed but also a change in the direction of the velocity. In this sense, a body traversing a circular orbit with constant speed has an acceleration. Galileo discovered that the acceleration of a stone falling to the earth is constant. Newton advanced the hypothesis that the acceleration of a planet in its orbit round the sun is proportional to the mass of the sun and inversely proportional to the square of the distance of the planet from the sun.

It was the great success of this hypothesis which encouraged Newton to venture a pattern of description which could cover every sort of motion in the universe. This general pattern is going to be our starting point. I shall present it in the form which has been used, after Newton, through the whole 18th and 19th centuries.

To understand the wide range of this pattern, we shall consider two types of motion as examples. The first is motion produced by direct push of bodies in the immediate environment upon the body to be moved. More specifically, we may think of a ball rolling upon a board or flying through the air, and then consider the way this ball is moved by the impact of the wind. The second example is that of a particle carrying an electric charge and moving in a field of electric and magnetic force. A specific example would be that of a cosmic-ray particle moving in the electric-magnetic field of the earth.

In both these cases, the acceleration of the moving body is connected in a simple way with the "state" of the environment in which the motion takes place. The acceleration of the flying or rolling ball is connected with the impact of the wind; the acceleration of the electrically charged particle is calculable by a simple formula from the intensity of the electric-magnetic field.

The formula to apply in each case has to be discovered for itself, but all such formulae for types of motion have one thing in common, according to Newtonian mechanics: under otherwise equal circumstances the acceleration of the moving body (ball or particle) is inversely proportional to its mass. The greater the mass, the smaller the acceleration. (For this purpose, we can mean by the word "mass" the weight of the body on the surface of the earth, and we can compare "masses" by comparing their weights at the same point on the earth. If they are weighed elsewhere, the weights will be different, but they will still have the same values in proportion to each other.)

The greater the mass of a rolling ball, the less its course will be altered by a given impact of the wind. The greater the mass of an electric particle, the less it will be deflected by a given electric-magnetic field. These are examples of the application of the Newtonian principle of acceleration. It is important that the reader note the use of

Editors' Suggestions

IN the confines of a magazine, it is not possible to be as complete in detailed explanations of common terms as the reader might desire. We have preferred to retain all of Dr. Frank's manuscript, in which he has endeavored to give a complete exposition of each idea (often repeating himself to make certain) and the reader is left to procure his own terminology references. Discussions of the conventional concepts of acceleration, mass, force, inertia, in physics and astronomy texts, will help the reader understand how Dr. Frank corrects and perfects such ideas in the light of original Newtonian theory.

It would be well to review *in elementary texts* Galileo's experiments with falling bodies, to check on one's understanding of his laws; to read several sources for Newton's laws of motion, noting particularly how the wordings by various authors differ; to restudy the law of gravitation and the application of its formula. Note that in this kind of study, every person has to figure out for himself, in his own mental language, the thoughts which the author expresses, but there is no need for an ability to use involved mathematics.

In these articles, only the concepts of *general relativity* are discussed, for they relate directly to Newton's gravitation and laws of motion, and they lead to the astronomical implications of relativity, as the reader will discover. In popular writing, special relativity—of time, of place, change of mass, length, and time with change of motion—has probably been treated more than general relativity. Perhaps, it is easier to ignore these concepts, as Dr. Frank has done, and to start where Galileo and Newton began.

the word *course,* which we shall return to later.

If we denote the mass of the body by m, the acceleration by a, and the "force" exerted upon the body by its environment by f, we can express the Newtonian principle by

$$m \times a = f \quad \text{or} \quad a = f/m.$$

The meaning of these formulae, which are well known in all problems of physics, is easy to grasp if the motion is rectilinear (in a straight line). But the formulae also remain valid if the body is deflected by the force from its rectilinear path. In this case, as stated before, acceleration also means a change in the direction of velocity.

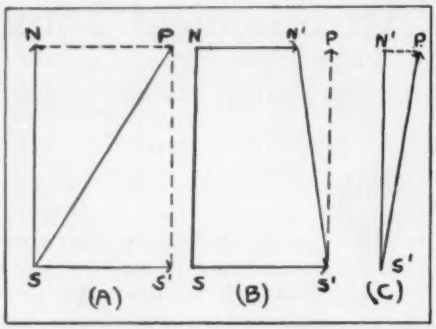
Obviously, from the formula, the motion becomes particularly simple if the mass m becomes very great. Multiplied together, m and a must equal f, so that as m approaches an infinitely large value, a shrinks toward zero. Therefore, great masses appear to move without acceleration in any field of force—they move with constant speed along a rectilinear path.

Applying this to our examples, a ball is almost not deflected by wind if its mass is very great—a ball of cork is deflected by any breath of wind, but a ball of lead is not disturbed in its course. A cosmic-ray particle is deflected in the magnetic field of the earth, but the path of a bullet carrying the same electric charge as the cosmic ray would not be influenced by the earth's electric-magnetic field.

Therefore, the paths of (relatively) great masses can be simply described—they move along straight lines with constant speed irrespective of their mass and of the particular field of force in which they are situated. The important result of this conclusion is that the paths of such great masses can be described in a purely *geometrical* way, without introducing any dynamical concept such as mass or force. This property of matter, to keep on moving along a straight line with constant speed, is called its *inertia,* and is usually expressed in Newton's first law of motion.[1] Actually, of course, only if a mass is infinitely great does it follow strictly its inherent inertia.

Now let us see how these concepts apply to a body of any given mass m which starts moving with a given velocity (given speed in a given direction). The motion which results in a given field of force can, according to Newtonian mechanics, be described by the following pattern:

The motion consists of two components. The first component is that which we have just described—independent of the field of force. The initial velocity (speed and direction) is preserved forever. The acceleration is zero. This component is called the *inertial* or *geometrical component,* since its description contains only a geometrical curve and no dynamical concept such as mass or force.



When a projectile leaves a place on the earth, it retains the motion due to the eastward rotation of that place. In (A), a projectile fired due north in the Northern Hemisphere has the motion SP, composed of SN and SS′, the latter due to rotation. But while the projectile moves to P, S moves to S′ and N moves to N′, as shown in (B). The north-south line becomes N′S′, and the projectile arrives east of N′, as shown in (C).

The second component is the departure from a straight line and/or from a constant speed. This acceleration a follows the Newtonian law, $a = f/m$. It depends upon "force" and "mass." However, this *dynamical component* disappears with the mass increasing to infinity. Therefore, the dynamical component is particularly relevant for small masses while the inertial component determines the character of motion of great masses. For an average mass (relative to its environment) we have to consider both components of its motion.

Thus the path of a ball is composed of the rectilinear *course* it would follow without the presence of the wind, and of the deflection caused by the currents in the air. If the mass of the ball is small, those currents practically determine the body's course, whereas great masses follow practically their inertial motion. Similarly, a light particle, if charged electrically, follows the deflection produced by the electromagnetic field, but a heavy particle preserves its rectilinear motion—the geometrical component being decisive in such a case.

2. The system of fixed stars[2] and the law of inertia

THE geometrical (inertial) component seems to be particularly simple because it is exactly a straight line. However, this matter is not as simple as it may appear to the beginner.

If we say that a body traverses a straight line "on the earth," we mean that it moves parallel to an edge of a room (for instance) which is rigidly connected with the earth. The rolling ball may, in turn, roll parallel to the edge of this room, or the electrically charged particle may fly parallel to an edge of a box in this room. If the term "rectilinear motion" is to make sense in physics, it must be possible to decide by experiments whether a body moves rectilinearly or not. Then the term has, to speak with P. W. Bridgeman, an "operational" meaning. We gave just such operational meaning to the term by referring to the edge of the room, which has become, therefore, a *body of reference.*

But a body which has rectilinear motion with respect to the earth obviously has not a rectilinear motion with respect to the system of fixed stars. A ball may move parallel to the edge of the room, but this edge is attached to the earth and is describing a rotational motion with respect to the stars. So the ball rolling along the edge is describing a kind of spiral curve with respect to the stars.

Now, in the popular formulation of Newton's laws of motion, one important point is often omitted. The statement, "The geometrical component of every motion is a rectilinear motion," has no operational meaning—therefore no meaning in physics at all, unless we add "with respect to the earth," or "with respect to the fixed stars," or "relative to a definite system of bodies of reference." With each of these additions, the statement has a definite meaning. But it is also evident that only with a particular one of these additions can the statement be true. For if a body of great mass describes a straight line with respect to the earth, it cannot describe a straight line with respect to the fixed stars at the same time.

Therefore, the system by which we define the meaning of rectilinear motion has to be mentioned explicitly in the statement of the laws of motion, *and by changing this system of reference we change the physical meaning of the laws of motion.*

A system of reference with respect to which the inertial (geometrical) component of the actual motion of bodies is rectilinear is usually called an *inertial system.* We can easily understand that our earth is not such an inertial system. At first glance the trace of a ball rolling in sand on the surface of the earth may seem to be a straight line. But if we observe this trace extended over many miles we shall notice definitely that it is curved (not considering the curvature of the earth). If we launch the ball toward the south, its path is bent toward the west, if we are in the Northern Hemisphere. If we are in the southern half of the earth, the deflection is toward

[1] According to Duncan's *Astronomy:* Every body continues in a state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by a force impressed upon it.

[2] Here and throughout the discussion the term "fixed stars" is used in a general sense, not with specific reference to the observed stars, nor meaning to imply that they are actually fixed.

the east. This is well known from the observation of projectiles and the circulation of air currents, and in the traditional presentation of mechanics this phenomenon is called the deflection of projectiles by the rotation of the earth. It is independent of the mass of the projectile, depending only on the initial velocity. But from our standpoint, the important point is that the deflection shows that the inertial component of the motion of projectiles with respect to the earth is a curved line, even if we neglect the effect of gravity and of the curvature of the earth.

On the other hand, if the ball were to roll on a plane which did not participate in the rotation of the earth, but which was at rest with respect to the fixed stars, the ball would describe exactly a straight line on that plane. This fact is well illustrated by Foucault's pendulum experiment, for details of which readers are referred to standard physics and astronomy texts.

Now it is worth repeating and completing our previous statements: The geometrical component of motion of any material body under any field of force is rectilinear with respect to an inertial system; or, if the mass is sufficiently great, the body will describe a straight line with constant speed (with respect to the inertial system) whatsoever the field of force may be. This last clause means exactly that a ball rolling through any distribution of wind will describe a straight line with respect to the fixed stars and a charged particle in any electromagnetic field will traverse a straight line with respect to the fixed stars, *provided that the masses of ball and particle are sufficiently great.*

Instead of saying "the mass is sufficiently great," the traditional formulation of the law of inertia says that "the field of force (wind or electromagnetic field) is sufficiently small or even vanishing."

We are now in a position to present the Newtonian pattern for the description of motion in general, and it follows directly from the statements in the second preceding paragraph:

> The motion of a mass consists of two components. The first, the geometrical component, is described as a geometrical curve, which does not depend upon the mass. The second, the dynamical component, has an acceleration which is smaller the greater the mass is. The geometrical curve of the first is particularly simple—a straight line—if we describe the motion with respect to an inertial system of reference, such as that of the fixed stars. If we use a system of reference which is in motion relative to the fixed stars, for example, the earth, the geometrical part becomes a more complicated curve. Its form depends entirely and only upon the system's motion relative to the fixed stars and is independent of the mass of the moving body.

(In the presentation of mechanics in textbooks, the curves traversed by moving bodies relative to rotating systems of reference are usually ascribed to "centrifugal forces" or "Coriolis forces." But the use of the term *force* in these cases produces confusion in the mind of the student and is a serious obstacle in understanding Newtonian mechanics and even more so in understanding Einstein. Curves ascribed to centrifugal forces belong actually to the geometrical component of the motion. They are not dependent on the mass of the body and have nothing to do with the dynamical component. To avoid all ambiguity, we have to reserve the term *force* for the circumstances accounting for the dynamical component of acceleration which becomes vanishing with increasing mass.)

3. Newton's general pattern of description fails to work in the case of "gravity"

IN applying a general method to a particular case, we often experience a peculiar result. The general method forsakes us just in the case which seems the simplest and with which we have most to do in our daily life. This is just what happens if we try to apply the Newtonian pattern of description (which we have just described in the proper fashion) to the type of motion of common objects: of a falling stone, of a projectile, of the earth in its orbit. This is usually called motion under the influence of the "force of gravity."

A falling stone falls with a certain acceleration which remains constant during its fall. To try to separate the geometrical from the dynamical component of the stone's motion, we replace it by another stone of greater mass but the same initial speed. We increase the mass again and again, but keep the initial speed unchanged. In the case of the ball flying in the wind, we found that with such increasing masses it was less and less disturbed by the wind and tended more and more to preserve its initial speed. So also was the case with the charged particle in the electromagnetic field. But not so with a falling stone; its acceleration remains the same no matter how large its mass becomes! Even the greatest mass fails to preserve its initial speed and to "resist" the influence of "gravity." In this case, then, we are unable to separate a dynamical component of motion from the geometrical one.

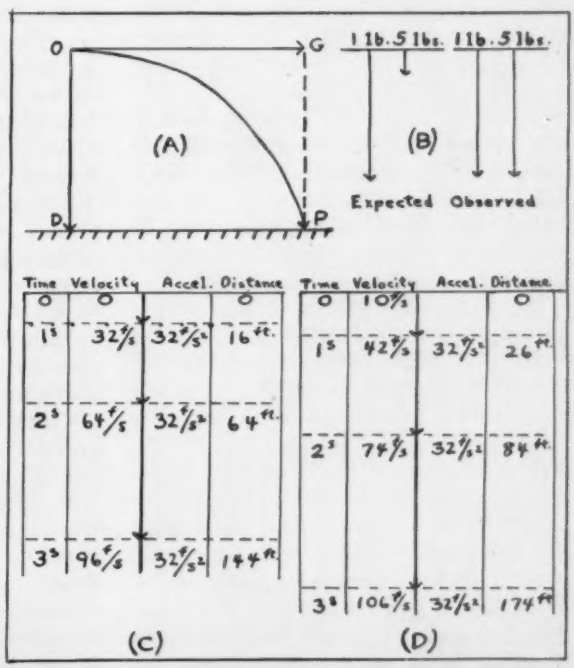
This is the important deduction from this observation: Since the curve (course) traversed by a body under the influence of gravity remains unaltered by increasing the mass, then according to Newtonian principles, *the whole motion behaves like the geometrical component and there is no dynamical component at all!*

How, then, did Newton proceed to fit this type of motion into his general pattern? As we know from every elementary textbook, he assumed that the force of gravity acting upon a stone of mass m is proportional to m. The greater the mass, the greater is the gravitational force attacking it. Mathematically speaking, he assumed $f = m \times g$, g being a quantity which varies from point to point in the field of gravity concerned; within a small domain, such as a room, g may be considered constant. Then, from the general pattern, Newton concludes:

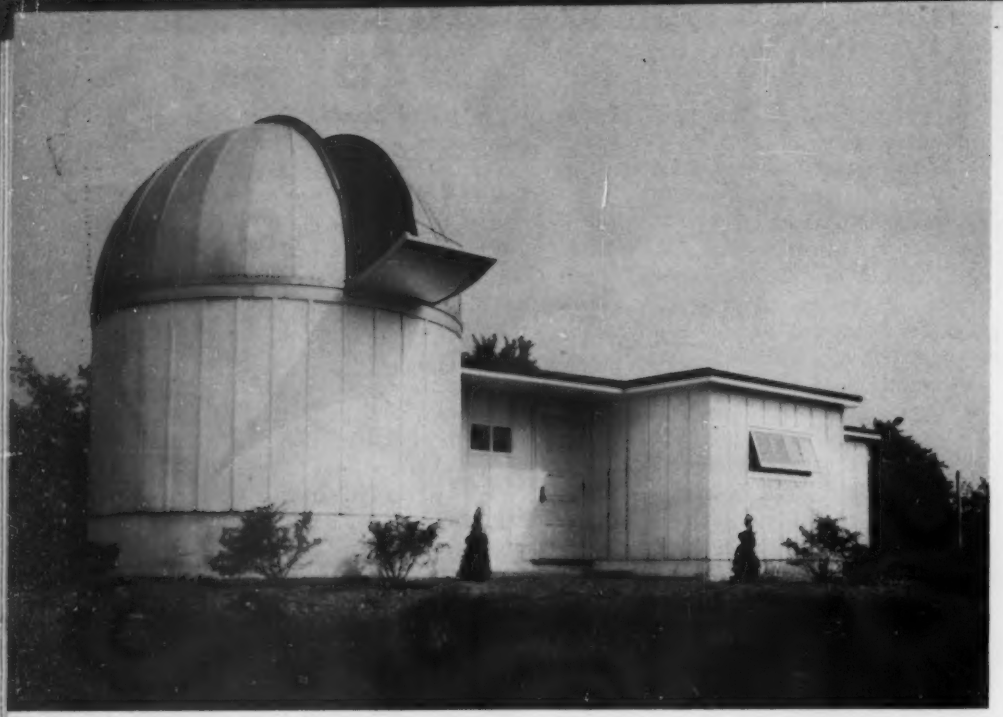
$$m \times a = f, \quad f = m \times g,$$
$$m \times a = m \times g, \quad a = g.$$

The mass cancels from both terms of the equation, $m \times a = m \times g$, and the result is that the acceleration becomes in-

(Continued on page 19)



The action of "gravity" on falling bodies. (A): A projectile shot in the direction OG will follow the path OP, reaching P in the time that a body dropped from O falls to D. OG represents the geometrical component and OD the dynamical, if we consider gravity as a force. (B): A one-pound body is expected to "fall" five times as fast as a five-pound body, if they are subjected to the same force, but they are observed to fall together. (C): The course of a freely falling body—time is in seconds from the start; velocity is in feet per second; acceleration is in feet per second each second; and distance is in feet from the start. (D): Like (C), with an initial downward velocity of 10 feet per second.



The observatory at R.P.I., just completed, has a 16-foot dome housing a 12-inch Newtonian telescope constructed in the Institute's shops, a transit house equipped with a professional 2½-inch transit and an astronomical clock, a small solar observatory, an observer's room, and a hall for exhibition purposes. Photos by Bert Boice, Troy, N. Y.

THE STUDE
RENSSELAER

By G. How

On the 25th of Septembe
dedicated in Troy, N. Y.
story of its develop

THE new Student Observatory at Rensselaer Polytechnic Institute is a material testimonial to what can be accomplished by the persistence of amateurs and the live interest of professionals, not only in astronomy but in other sciences, art and education, as well.

The observatory is the latest addition to the resources of the Astrophysical Society of Rensselaer Polytechnic Institute, an organization of undergraduate students. Its purpose is to foster an interest in all matters pertaining to astronomy and to provide such facilities as will enable its members to put these interests to work.

Two freshman students, Ellis Hormats and Edward Clements, who had started the construction of telescopes before coming to the Institute, were anxious to obtain facilities to complete their projects, and they also desired to organize an astronomy club. They approached the powers that be, and after they had made a sufficient nuisance of themselves, the facilities were forthcoming. The necessary amount of money was privately donated to get the project under way, and the organization was launched.

In laying out the structure of the organization for the students, it was felt that the new Astrophysical Society should devote itself to actual accomplishment in the science, rather than merely to its letter; and should be able to take full advantage of the resources of the Institute and of the possible varied interests of its members. And so, sections on instrument making, observing, and special projects were set up, as well as a section on general sessions. Each section has a chairman and these chairmen together form an executive committee which administers the general affairs of the organization. The response was immediate and enthusiastic.

It was, of course, at once apparent that this new society should have a telescope. Surely, it could do no better to prove itself than to undertake the construction of the instrument. A Herschel was needed for this, and he was found in the person of Otto Rasmussen, instrument maker for the department of physics. Mr. Rasmussen, who comes from Denmark and is a true spiritual descendent of Tycho Brahe, had just completed a fine 6-inch telescope of his own. He was anxious to help.

It was decided to undertake a 12-inch Newtonian reflector with a focal length of 65 inches. This would give richest-field characteristics and seemed best for both visual and photographic purposes. The early grinding was done by the students, but the final polishing and figuring, as well as the design and construction of the fine mounting, were executed by Mr. Rasmussen.

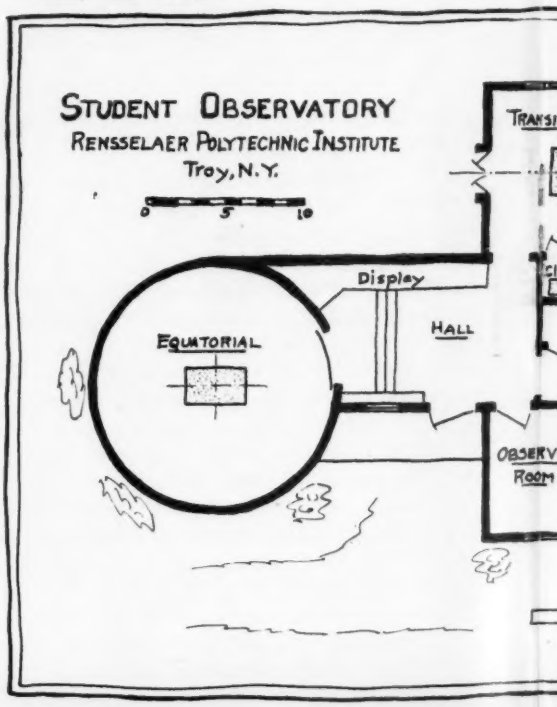
The mounting of the telescope is a version of the fork type, its polar axis being supported on three widely spaced precision ball bearings donated by the New Departure Manufacturing Co. This gives a firm, three-point support, a complete lack of any loose fitting, and a very stable motion.

Quick setting is accomplished through a friction fit by four conveniently spaced handles. The setting circles are marked with white lines on black; the slow motion in declination is controllable at the eyepiece and at the mirror end of the tube. The right ascension drive, which is by a synchronous motor on a vibrationless mounting, is controlled for guiding by an electromagnetic gear shift which either cuts out the drive or doubles its speed. This is hand-switched at the end of a long cord, usable at any part of the instrument.

The main 12-inch pyrex mirror is mounted in a cell on six cork-covered fingers. The mirror was chromium-aluminized by Dean S. C. Hollister, of Cornell University.

At 90 degrees to each other, there are two positions for the eyepiece and diagonal, both of which can be readily shifted for convenience in observing. A plate holder for 2 x 2-inch plates is mounted at the prime focus, conveniently arranged for fine focusing and for ready removal. The instrument is not provided at present with a finder, but it is believed that the setting circles, and a set of sights, will be adequate.

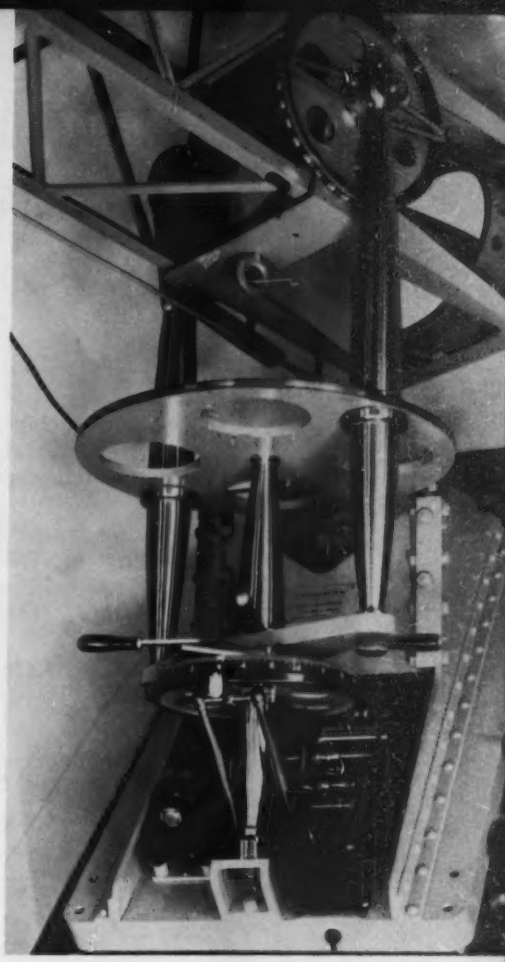
When the telescope began to be a reality, it was apparent that it would need a roof over its head. And so, a new project was undertaken—one of greater difficulty and significance—that of an observatory. Plans were drawn up, drawings were prepared by a student in architecture (a member of the society), estimates were obtained, a model was constructed, and finally, our President Hotchkiss was approached. He said, "Go ahead!"



UDENT OBSERVATORY AT R POLYTECHNIC INSTITUTE

G. HOWARD CARRAGAN, *Rensselaer Polytechnic Institute*

ptember an observatory designed for student and public use was N. Y. Its principal telescope is pictured on our front cover and the development through the interest of amateurs is told herein.



A close-up of the 12-inch reflector reveals details of the mounting, driving mechanism, and circles. The telescope, as it appears installed in the dome, is our front-cover photograph this month.

It was at this time, however, that an astronomical transit which had been put away for many years was unearthed, and this gave reason to enlarge the proposed building. Such an undertaking demanded a Sir Christopher Wren, and this was found in the person of Prof. Ralph Winslow, head of the department of architecture. After the inspection of several small observatories, Prof. Winslow made new plans, to which President Hotchkiss again gave approval. Students assisted with the painting and interior finish of the building. They were helped in this by Wilfred J. Brooks, of the Troy Astronomical Club, our local amateur society.

The layout of the observatory is apparent from the picture and the plan view. Its floors are of concrete throughout; the walls of standard frame construction, covered with ⅜-inch waterproof plywood. The roof is a built-up tar roof.

A 16-foot dome of 22 gores was wood framed and covered with ¼-inch tempered presdwood and given two coats of aluminum paint. It is supported on eight heavy truck casters and is moved manually by the usual bar. The slit is 41 inches wide and its roll-over cover is operated from within by a worm-gear hoist. For the transit house slit, a simple trap-door cover is provided.

An insulated, temperature-controlled cabinet contains the clock, which is a fine precision astronomical instrument, rebuilt and contributed to the observatory by Mr. Rasmussen. For time and position work, there will be accessory radio equipment.

On observing nights, the observer's room may be heated with an electric heater. This room has insulated walls, a workbench and desk, cabinets for instruments, and shelves for a library.

Ancient constellation figures in silver on blue decorate the ceiling of the entrance hallway, which is designed as an exhibition space. There are display cases for astronomical models and exhibits, and a number of transparencies of celestial photographs. A specially designed ceiling fixture shows by transmission a copy of an early star map. The main door of the building contains 15 panels, in which are shown in relief each of the signs of the zodiac and the signs pertaining to the sun, moon, and earth.

Around the observatory will be a small sundial court, with vertical and horizontal dials of varied design, two illuminated observing stands, and a post for carrying a 3¼-inch refractor. The observatory is expected to be an attractive part of the campus.

The location was chosen for its accessibility. There is an excellent horizon, and while there will be the usual trouble from city lights, it was felt that its convenience for the students, as well as for the people of the city, meant that it would be used much more than otherwise.

The project has, of course, been set up with the resources of the amateur in mind. However, the equipment is thoroughly professional in character, and some work of astronomical value, such as meteor and variable star observing, will be undertaken. The small solar observatory, the equipment for which is now under student design, will offer another possibility.

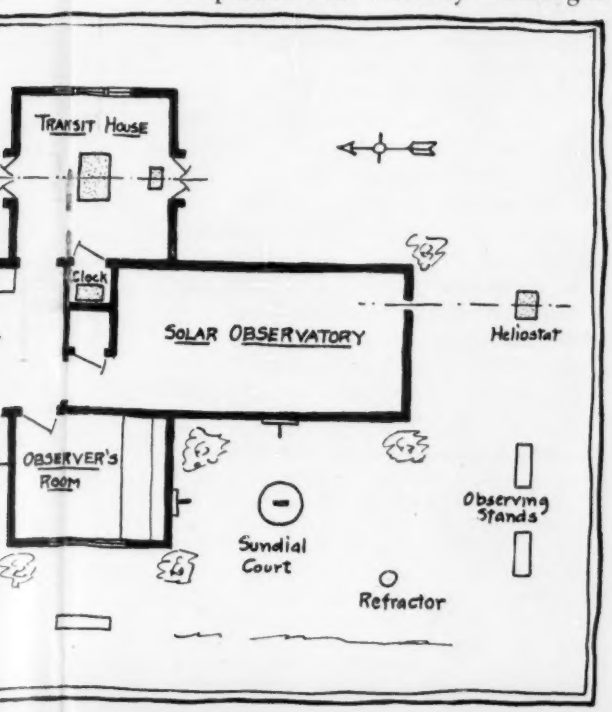
Although there is no regular academic work in astronomy at Rensselaer Polytechnic Institute, it has not been difficult to interest students from the various departments in astronomical problems. Two senior graduation theses on the development of photoelectric methods for telescope guiding have been undertaken by students of electrical engineering. A chemistry student is studying chemical reduction methods for the increasing of star counts from photographic plates.

At present, there is a student optical shop for the processing of mirrors and for other optics, a student machine and carpenter shop for the making of mountings, and the observatory. The resources of the optics laboratory of the department of physics are also available.

Prof. Edwin B. Allen, head of the department of mathematics, is also helping by offering an extracurricular course in astronomy and navigation. Projects of these types give the student an opportunity to develop his own initiative.

September 25th, in the evening, marked the formal opening of the Student Observatory, with the dedication address by Prof. Bart J. Bok, of Harvard College Observatory. Thereafter, the observatory is available for the use of interested students and for serious study. At stated intervals, public open nights will be held.

It is hoped that this undertaking, which has been in numerous ways the personal gift of the efforts and thought of many interested students, faculty, and workmen, will be a real service to the community and to the science.



BEGINNER'S PAGE

Tides and Their Variations

By Percy W. Witherell

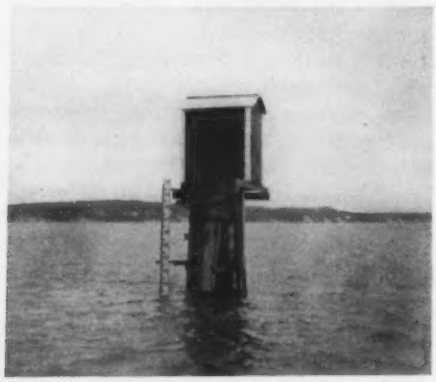
WHEN one speaks of the tide, it usually brings to mind the phenomena of one's own experience in vacationlands along the coast. To a sojourner on the northern New England shore, the tide suggests a difference of about nine feet in height between high and low water in an interval of about six and a quarter hours. Along the middle Atlantic coast, ranges of from three to six feet are seen, and lesser amounts occur in the Caribbean Sea.

To the inhabitants of Puerto Rico, Port Said, Messina, Marseilles, and Oslo, the less-than-a-foot changes in the level of the water on the shore mean nothing. At the other extreme, the terrific changes of 30 to 45 feet that are familiar to the people of the Bay of Fundy, Nova Scotia, Granville, France, and Bristol, England, signify great danger to anyone caught unawares. In the Pacific, there is a similar range of from one foot in the Hawaiian Islands to 28 feet in Penjinski Bay in Siberia.

On being told that the tides are caused by the attraction of the moon and the sun, those accustomed to one foot changes accept it calmly, but those with experiences of 30 to 45 feet are overawed and possibly a little skeptical. However, a consideration of the above examples simplifies the problem. It is noticed that the open waters have a rise of only a few inches, as do those of "inland seas," but this moderate rise in the open sea becomes a flood when it rushes into a narrow channel or is caught between two continents, as in the Bering Sea.

It is well, also, to distinguish between the vertical rise, or *tide*, and the *tidal currents* which result from transitions of this change of level from one part of the ocean to another. In some basins with narrow inlets, the flood current may flow in for as long as three hours after the time of high tide. The *bore* of a river (such as the Seine) may travel 100 miles up the stream before subsiding.

It might be expected that the high tide would occur when the moon crossed the meridian. But it does not, so to determine the time of high tide from observations of the moon, one must know the *establishment of the port*, which is the time from the moon's passage to the next high tide. At New York it amounts to about eight hours, so the moon which caused a particular tide will already be below the horizon when that tide reaches its maximum. However, another effect, known as the *priming* and *lagging* of the tide, is introduced by the sun's tidal effort, so the actual time of high tide cannot be predicted from the establishment of the port alone.



The tide station at Cook Inlet, Alaska, has an automatic gauge installed in the house on top of the piles. Note the tremendous range from low tide (left) to high tide (above), as the waters of the Pacific get caught between two continents. Engraving, courtesy "The Ensign" and the U.S.P.S.

When the sun and moon are in line, at full moon and new moon, their combined gravitation increases the tidal effect, and there result *spring tides*. These have the greatest range from high to low tide, but nothing to do with the season of the year of the same name. *Neap tides*, of smallest range, occur at the first and third quarters of the moon, when the sun and moon produce tidal actions balanced at 90 degrees to each other. An explanation will be given later of how the attractions of the sun and moon bring about these results, and of the mechanism of the tide-producing effect.

The action of the alignment of the sun and moon at full and new moon does not take effect immediately in all parts of the world. In fact, it seems to move similar to a great current, beginning in the Pacific Ocean and moving around South America into the Atlantic. As a result, while spring and neap tides occur at North American Pacific ports almost simultaneously with corresponding lunar phases, they are a day late on the American Atlantic coast and two days late on the European.

Another factor which influences the range of the tides is the change in the moon's distance during the month. This change amounts to about 12 per cent of the average lunar distance of 240,000 miles. The sun's distance changes too, but by only about three per cent, and in a yearly instead of a monthly cycle.

It is evident that the times of high and low tide are influenced by many factors, astronomical, meteorological, and geographical. As a result, it is necessary to make a long series of observations of the tide at a particular station before reliable predictions of future tides can be published. However, the task is simplified by automatic tide gauges which are in continuous operation at certain carefully selected points along our coasts. They are maintained by the United States Coast and Geodetic Survey. The selected points are called primary stations; tide predictions for other points in their vicinity can be checked by the primary station records. A tide-predicting machine, 10 feet long, six feet high, and two feet wide, with 15,000 separate parts, can combine all the tidal factors to compute the tides for any locality.

An exact knowledge of the time and range of the tides and tidal currents is of great importance to the navigator. In Bowditch's *American Practical Navigator*, in the first edition of 1802, there are given tables for 44 American and 40 foreign ports from which the desired results could be calculated by the navigator himself. In 1942, however, the Coast and Geodetic Survey publishes four separate volumes annually, two tide tables and two current tables. One set is for the Atlantic Ocean and the other for the Pacific and Indian Oceans. They show exact figures for every day of the year for 108 reference ports, and other tables give the times of tidal differences for hundreds of secondary ports and places. The navigator is left to do very little computing for himself.

It has been suggested by some of our readers that definitions of astronomical terms frequently used in *Sky and Telescope* would be helpful. Any lists of puzzling words that readers of this page may care to send in will be a welcome help in compiling a table of such terms.

SAILING THE SEVEN SEAS

(Continued from page 7)

forced him to educate himself in spare time after he was 10 years old, which he did with such zeal and ability that at the age of 21 he was unusually well informed and an outstanding mathematician.

"In 1795, Bowditch went to sea on his first of four voyages as supercargo and captain's writer. A fifth voyage he made as master and part owner of a ship, returning to Salem in 1803, to retire to his studies and the insurance business.

"Early during these voyages, Bowditch became keenly interested in navigation and missed no opportunity to take observations of and to study the movements of celestial bodies. The most recent volume on navigation at the time was Hamilton Moore's 'Navigator,' published in London. Many errors were known to exist in the book. To have exact tables for his work, Bowditch commenced the laborious task of recomputing Moore's tables. He found the book poorly arranged for practical navigation, with inadequate tables, and to contain numerous errors. One error was said to be so serious as to have caused the loss of two ships at sea. When he communicated his findings to the American publisher of the book, Mr. Edmund Blunt of Newburyport, Mass., who was about to publish a third edition in this country, Mr. Blunt urged Bowditch to take several copies of Moore's book on his next voyage to correct it for the third edition. The task involved such extensive revision that Bowditch decided to write his own book, and to 'put down in the book nothing I can't teach the crew.' On that trip it is said that every man of the crew of 12, including the ship's cook, became able to take and calculate lunar observations and plot the daily position of the ship.

"In 1802, Mr. Blunt published the first edition of the American Practical Navigator, which was received with such great acclaim by the maritime world that over 30,000 copies in 10 editions were sold prior to Bowditch's death. In 1866, the United States Hydrographic Office bought the copyright and since that time has published the book, revising it completely from time to time to keep step with the modern changes in navigation methods.

"Death at 65 on March 16, 1838, closed a record of wonderful achievement during a life of stainless integrity. Many honors had been conferred upon him by his fellow men. The following eulogy was written by the Salem Marine Society:

"'In his death a public, a national, a human benefactor has departed. Not this community nor our country only, but the whole world has reason to do honor to his memory. When the voice of eulogy shall be still, when the tears of sorrow shall cease to flow, no monument will be needed to keep alive his memory among men; but as long as ships shall sail, the needle point to the north, and the stars go through their wonted courses in the heavens, the name of Dr. Bowditch will be revered as of one who has helped his fellowmen in time of need, who was and is a guide to them over the pathless oceans, and one who forwarded the great interests of mankind.'"

About the time of Bowditch's death, another great step was taken in the art of sailing ships. In 1837, Capt. Thomas H. Sumner, skipper of an American Merchant vessel, discovered the principle of what is now known as a Sumner line, or line of position. The historical background and present applications of Sumner's contribution were discussed in Dr. Watson's article last month.

Many shortcuts, tables, and devices have been developed for navigators in recent years; some of these will be treated in later articles. The future, with great passenger and freight planes, glider trains, and dreams yet undreamt, may bring new devices and methods, all to help guide those who sail on and over the seven seas.

ASTRONOMICAL ANECDOTES

MORE PI, A ROGUE, AND A KING

IN the August issue, I threw in a pair of mnemonic devices for remembering the value of the constant π. I have since been led to believe that unless one can write down the value of this constant to at least 30 decimal places, he can hardly consider himself acquainted with the subject. My intention was to provide something easy to remember, but if one wants to learn much longer jingles, almost as easy to memorize as the digits themselves, here are a few more, recalled to my attention by James Stokley. They all appeared in *Science News Letter*, Vol. 10, pp. 31, 111, 143 (1926). By counting the number of letters in each word, the successive digits of the value of π are obtained.

Denham Larrett, in *The Story of Mathematics*, gave this:

Sir, I send a rhyme excelling
In sacred truth and rigid spelling;
Numerical sprites elucidate,
For me, the lesson's dull weight.
If nature gain,
Not you complain,
Tho' Dr. Johnson fulminate.

For those inclined toward French, here's one from *Elementar Lehrbuch der Algebraischen Analysis und der Infinitesimalrechnung*, by E. Cesaro, translated into German by G. Kowaleski, Leipzig, 1904.

Que j'aime à faire apprendre un nombre utile aux sages!
Immortel Archimède, artiste ingénieur
Qui de ton jugement peut priser la valeur?
Pour moi ton problème eut de pareils avantages.

A third one, which must be included, was sent by Mr. Stokley and later by Herbert W. Cornell. It comes from Robert E. Moritz' *Memorabilia Mathematica* and other works, but it is supposed to be quite old. It has been called, "Ode to Archimedes."

Now I, even I, would celebrate
In rhymes inapt the great
Immortal Syracusan, rivaled nevermore,
Who, in his wondrous lore,
Passed on before,
Left men his guidance how to circles mensurate.

Over a period of many months, there have accumulated quite a number of interesting odds and ends, most of them in letters I have received from readers of *Sky and Telescope*.

J. F. Hawk, of Petrolia, Pa., has unearthed an example of a possible rogue among astronomers, and has sent me an interesting pamphlet with the title, "Blennerhassett Island and the Burr Conspiracy"; the author is Norris F. Schneider, the Courier Company, Zanesville, Ohio.

In the Ohio River, 14 miles below Marietta, lies Blennerhassett Island. It gained its name from that of Harman Blennerhassett, an Irish aristocrat who lived on the island from 1797 to 1808. His chief interests were "science, literature, and music. . . . By means of a fine telescope he studied astronomy."

Aaron Burr, embittered by his loss of the presidency to Thomas Jefferson and ostracized because of his having killed Alexander Hamilton in a duel, met Blennerhassett at Marietta in 1805, and the latter showed a willingness to join Burr in his plan to set up an independent nation. Burr's expedition to attack New Orleans was organized on Blennerhassett Island in 1806. The two were arrested together, but neither was convicted of treason.

Mr. Hawk says in his letter, "It would be interesting to know where the telescope is," but I suspect it was a pretty small one, quite easily lost or destroyed.

Another telescope, not small even for our own times, was the great 48-inch reflector of the elder Herschel. Dr. Lewis Carson, of Santa Barbara, has been reading *Memoir and Correspondence of Caroline Herschel*, by Lady John Herschel (Appleton, 1876). It's a fascinating book, containing many anecdotes of the lives of all the Herschels. Dr. Carson refers particularly to one in which the events of August 17, 1787, are described.

Before the optical parts were installed in the great tube of the telescope, the King, the Archbishop of Canterbury, the Queen, the Duke of York, and some of the Princesses visited Slough and walked through the tube. Canterbury was having a hard time following the King through the tube, whereupon George III turned to him, grasped his hand, and said, "Come, my Lord Bishop, I will show you the way to Heaven!"

R.K.M.

BOOKS AND THE SKY

ASTRONOMY, MAPS, AND WEATHER

C. C. WYLIE. Harper & Bros., New York, 1942. 447 pages, $3.00.

ASTRONOMY, MAPS, AND WEATHER is written to fill a definite requirement. This is clearly explained in the introduction, and must be kept in mind by the reviewer and the prospective reader. The training program for Air Force pilots has, by necessity, been accelerated to the maximum possible speed. One of the limiting factors is the unfamiliarity of the prospective pilots with the astronomical and meteorological subject matter to be assimilated. This book is written to be used as a text in the pre-flight training classes now being established in high schools and colleges. At what point in this training program the book will be used is not clear, but presumably it is during the first or second year of college work.

The book consists of four main parts. In the first, which is of six chapters, the characteristics of the celestial sphere, coordinate systems, constellations, telescopes, the earth and its motions, and the seasons, are all briefly considered. Numerous drawings aid in clarifying the text. Fourteen constellation maps, as well as sketches of particular configurations, are designed to assist in the identification of the navigational stars. The projection of these maps is novel and adapted to use from middle northern latitudes, so they are undoubtedly of considerable interest and value to amateur astronomers in the United States. Although a map of southern circumpolar constellations is included, the general maps will be difficult to interpret in southern latitudes, where many of our student pilots are eventually sure to go.

The second part, containing three chapters, introduces the elements of practical meteorology through "Weather," "Clouds," and "Weather Forecasting." Numerous photographs illustrate the cloud forms and atmospheric phenomena which the navigator and aviator need to recognize. The practical side of weather problems is emphasized over the theoretical. Actual conditions the aviator is bound to encounter, such as rain, ice formation, and wind changes, are dealt with to considerable extent in spite of space limitations.

Part three, also consisting of three chapters, presents the fundamental problems of practical navigation. Maps and charts, their differences in symbols and projection characteristics, are introduced in a simple manner. Time and the almanac, watches and chronometers, and sound advice on the care of timepieces fill one chapter. The basis of celestial navigation comprises a large chapter. Although the navigational formulae are given, no examples have been worked out. However, the enterprising student and the informed instructor will use the problems provided at the end of this chapter for exercise in the numerical work.

The remaining eight chapters constitute the fourth part of the book. Here its dual purpose, as explained by the author, is apparent, for these chapters contain general descriptions of the heavenly bodies. So far as navigation and other immediate purposes are concerned, this part of the book "may be conveniently omitted until conditions are more favorable for reading and enjoying it." The author obviously hopes that the student will go through these final chapters and gain some general knowledge of astronomy. Here again, amateur astronomers will find valuable reading.

The large number of pages attests to the quantity of material in the book, and to the profuseness of its illustrations and diagrams, many of which will be new to most amateurs. The execution of the star charts makes them very attractive. Where it is shown, the celestial equator does not meet the horizon at the points marked east and west, which is a minor inconsistency, but to one accustomed to other star charts it gives the horizon the appearance of having square corners.

Although prepared in a short time, the text is well-organized and practical—it will serve the purpose for which it was written. As a whole, the volume shows the careful and detailed consideration Prof. Wylie has given these subjects during his teaching at the University of Iowa.

FLETCHER G. WATSON
Harvard College Observatory

PHYSICAL SCIENCE

EHRET, SPOCK, SCHNEIDER, VAN DER MERWE, AND WAHLERT. The Macmillan Company, New York, 1942. 639 pages. $3.90.

CONSTANTLY during the course of one's reading in astronomy and its closely allied fields such as meteorology and spectroscopy, references to the basic sciences of physics, chemistry, and mathematics are found. If the understanding of these references is clear and immediate, it is usually easy to grasp the astronomical situation under discussion, but if such references stir up only vague visions of early days in laboratories in high school and college, the astronomy comes harder.

An easy remedy for those who find themselves in this second "state" is provided by such a book as this, which, in spite of its multitudinous authors, is a coherent whole, covering the entire range of sciences basic to astronomy. It is not, however, written in the journalistic manner, as have been so many of our recent popular science survey books. In fact, it is not even a survey in the usual sense. Rather, it is like a collection of material from a score of textbooks, written in the academic manner, which makes it basically sound science.

The volume is well illustrated, but its astronomy chapters (the first in the book) have no unusual pictures. By digesting its 35 chapters totaling 624 pages, an amateur astronomer can put himself on even terms with any scientific terminology he might meet.

C.A.F.

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NEWS NOTES

By Dorrit Hoffleit

LETTER FROM RUSSIA

Before 1937, Dr. V. Zessewitsch, then director of the Tadjik Observatory, Stalinabad, U.S.S.R., published many technical papers, especially about eclipsing variable stars. Since then no one seems to have heard anything about him. But now Dr. S. Gaposchkin, a former Russian now at Harvard, is happy to share a letter he has just received, dated April 24, 1942.

From 1937 to February, 1942, Dr. Zessewitsch had been at Leningrad, where he taught at the Astronomical Institute of the Academy, was professor at the Pedagogic Institute and dean of the physical-mathematical faculty. He has been investigating methods for determining the orbits of eclipsing binary stars, and has written a 200-page book on the subject. He suggested that copies of the book might become available by applying to the People's Commissar in the Society of Cultural Exchange with Foreign Countries (in U.S.S.R.). At the time of writing the letter, Dr. Zessewitsch was back in Stalinabad, and ready to publish over 65,000 variable star observations, especially on the stars XZ Andromedae, RS Arietis and RU Piscium. These are indeed cheerful tidings after so long a silence.

A.A.V.S.O. TO MEET

The 31st annual meeting of the American Association of Variable Star Observers will be held at Harvard College Observatory on October 9th and 10th. A Council meeting at 5:00 p.m. Friday will be followed by a joint meeting with the Bond Astronomical Club at 8:00 p.m. The annual business meeting and technical session will convene at 10:00 a.m., Saturday. That afternoon the members will attend an observatory colloquium on variable star studies. An informal dinner and get-together will close the program Saturday evening.

EMPHASIS ON COMETS

Readers of *Sky and Telescope* may have seen the *Astrophysical Journal* mentioned more frequently than the *Astronomical Journal*. The latter is, however, as important for the publication of technical papers related to positional astronomy as the former is to papers on spectroscopy and other phases of astrophysics.

It is not surprising, then, to find that the recent issue of the *Astronomical Journal* (published at Yale Observatory) contains five papers on comet orbits and positions. These five constitute half the issue; of the remainder, three papers give observations of occultations, one is a list of stellar parallaxes, and two concern general computing methods, which are especially applicable to cometary problems.

The position of a comet is found by measuring the location of the image of the head of the comet on a photograph. But the exposure time might make a difference in our measurements, especially if the image is somewhat lopsided. This problem is dealt with by V. Goedicke in one of the papers mentioned. He measured Yale photographs taken in February, 1941, of Comet Cunningham, for which the exposure time varied from 10 seconds to three minutes. With the shortest exposure, the images of the nucleus of the comet did not differ appreciably from star images, but on the longer exposed pictures a clearly developed coma almost merged with an overexposed nucleus.

Dr. Goedicke found that within this range of exposure, measurements of the comet's position did not depend on the exposure time; the error in the measurement of a single photograph is about 0″.2 in each co-ordinate.

Perhaps the most exciting comet paper is the belated publication of a computation of an ephemeris for periodic Comet Forbes, 1929 II, made a year ago by N. Makarov, of the University of Kasan, U.S.S.R. The comet, which was expected to return in 1942, had not been observed since 1929, and as its orbit was not very accurately known, Makarov states that his predicted time of the closest approach of the comet to the sun (perihelion passage) might be in error by as much as eight days. Meanwhile, an ephemeris by F. R. Cripps in the *Handbook* of the British Astronomical Association for 1942 gave a date for perihelion passage differing only a quarter of a day from Makarov's.

On June 18th, this year, before Makarov's calculations were known to astronomers in general, G. Van Biesbroeck rediscovered the comet at Yerkes Observatory as a 15th-magnitude object. It had arrived at perihelion on April 15th, only a day and a quarter before the time predicted by Makarov.

AN AMATEUR AND THE WAR

The common soldier whose hobby was the stars may find that his present duties afford him even greater pleasures in that hobby. This is evidenced from parts of letters from a British amateur, N. F. H. Knight, reprinted in the *Journal* of the British Astronomical Association. On his voyage from England to the Middle East he was thrilled to see the Southern Cross and the Magellanic Clouds. In the equatorial latitudes the short duration of twilight made Mercury a very conspicuous object long after dark. The zodiacal light was a perfectly common sight every moonless night.

NOVA IN CYGNUS

On September 16th, Harvard Observatory received a telegram from Mt. Wilson Observatory about a new star just discovered by Dr. Fritz Zwicky at Mt. Palomar. The nova is in Cygnus, not far from Epsilon Cygni in the Northern Cross; its position is R.A. $20^h\ 56^m\ 30^s$, Dec. $+35°\ 42'$. Its spectrum shows bright bands with multiple absorption components.

This new star appears on more than 50 Harvard plates taken since June 8, 1942, its apparent magnitude fluctuating between the 11th and the 7th magnitudes as if it had reached its explosive maximum in the early spring, when the constellation was too near the sun to be seen. The nova's distance is probably greater than 1,000 light years. It will probably gradually fade from its present brightness of about the 9th magnitude visual.

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GLEANINGS FOR A. T. M.s

EDITED BY EARLE B. BROWN

DESIGNING AN ACHROMATIC OBJECTIVE—II

(Continued from the August issue)

2. Sign Conventions. In order to make our equations completely general for dealing with all possible cases, both concave and convex surfaces, with intersection-lengths to right or to left of the surface, with rays above and below the axis, and with rays at all angles, we must adopt certain sign conventions, as follows:

a. Angles I and I′ are measured *from the ray to the normal.*
b. Angles U and U′ are measured *from the axis to the ray.*
c. All angles are counted positive if, when measured as in a or b above, the motion is clockwise; negative, if the motion is counterclockwise.
d. Radii of curvature are counted positive if the center of curvature lies to the right of the surface, negative if it lies to the left.
e. Intersection-lengths are counted positive if the intersection lies to the right of the surface, negative if it lies to the left.
f. All ray-tracing proceeds from left to right.

The validity of these sign conventions will not be demonstrated here, but it may be done with diagrams. We deem it sufficient to state that if the quantities are used in the equations with the sign conventions as above, the quantities derived therefrom will have their signs according to these conventions.

3. Logarithms. A word with regard to the logarithms of negative numbers and of numbers less than 1.00 is required for those who are not completely familiar with logarithmic computation. As to the use of logarithms, the reader may refer to any textbook on trigonometry. Five-place logarithms are sufficiently accurate for any but the most precise computations.

The logarithm of a number less than 1.00 has a negative characteristic and a positive mantissa. In these cases, we use the *complement* of the characteristic, and call it positive. For example, the logarithm of 0.2 is (—1).(30103). The complement of 1 is 9; therefore the required logarithm is 9.30103. At the conclusion of the computation, we must subtract 10 from the characteristic; for example, suppose we had the computation (2.0) (0.2) (0.02). Our figures would be as in Table I-a. The antilogarithm of 7.90309 is .008, remembering that 7 is the complement of 3. If we were to consider 7 as the characteristic, our answer would be 80,000,000, obviously absurd. This computation can be carried out by simply ignoring the "tens" column of the characteristic, since the quantities with which we shall be concerned are not of sufficient range to raise any question as to whether the resulting figure is a complement or not.

Table I

(a)		(b)		(c)	
2.0	0.30103	2.0	0.30103	2.0	0.30103
0.2	9.30103	—0.2	9.30103n	—0.2	9.30103n
0.02	8.30103	0.02	8.30103	—0.02	8.30103n
0.008	7.90309	—0.008	7.90309n	+0.008	7.90309

Theoretically, a negative number cannot have a logarithm. But we can call all our numbers positive, and then introduce the proper sign at the end of the computation. Of course, we have to apply the ordinary rule of multiplication and division, whereby the product of two negative numbers is positive. For example, consider the multiplication of (2.0) (—0.2) (0.02), Table I-b, and of (2.0) (—0.2) (—0.02), Table I-c. Here we suffix an n to each logarithm whose antilog is negative. If the total number of n's is odd, the answer is negative; if the total number of n's is even, the answer is positive.

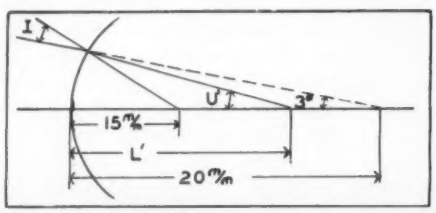

Fig. 3. Quantities in our sample case.

4. Computation form. Let us try, for a sample case, a convex surface of radius 15.000 m/m, refractive index N′ = 1.5200, and trace a ray with intersection-length 20.000 m/m and intersection angle 3° 00′ 00″. Therefore, N = 1.0000, N′ = 1.5200, L = 20.000 m/m, U = 3° 00′ 00″. The computations by equations (1) to (5) from our first installment are shown in Table II and result in a value of L′ of 17.953 m/m.

Table II

Equation (1) gives:		**Equation (3) gives:**	
L	20.000	U	3°00′00″
−r	15.000	+I	0 59 59 (1)
L−r	5.000	U+I	3 59 59
log (L−r)	0.69897	−I′	0 39 27 (2)
+log sin U	8.71880	U′	3°20′32″
log (L−r)sin U	9.41777	**Equation (4) gives:**	
−log r	1.17609	log r	1.17609
log sin I	8.24168	+log sin I′	9.05984 (2)
I	0°59′59″	log r sin I′	9.23593
Equation (2) gives:		−log sin U′	9.76567 (3)
N/N′ is 1/1.52000 or		log L′−r	0.47026
log N/N′ is −log 1.520		L′−r	2.953 m/m
log sin I	8.24168 (1)	**Equation (5) gives:**	
+log N/N′	9.18184	L′−r	2.953 m/m(4)
log sin I′	8.05984	+r	15.000
I′	0°39′27″	L′	17.953 m/m

We can set up our computations in a convenient form, as in Table III, first column. This avoids recopying data which is transferred from one equation to the next. We start with the initial L and subtract r, entering the logarithm of the result on the next line. We add log sin U and subtract log r, obtaining log sin I. This completes equation (1), and we look up the value of angle I and enter it in the angle register on line 16, having already entered the value of the initial U on line 15. Log sin I′ is one of the data for equation (2), so we enter log N/N′ and add. Log N/N′ is negative, because N′ is greater than N. We could more properly add log N and sub-

Table III*

Quantity	COL. 1 Marginal 1st. Surf.	COL. 2 Ray 2nd. Surf.	COL. 3 Paraxial 1st. Surf.	COL. 4 Plane Surface
1 L	20.000	17.703	Same	20.000
2 −r	−15.000		"	
3 L−r	5.000		"	
4 log (L−r)	0.69897		"	
5 +log sin U	+8.71880	8.76567	"	
6 log (L−r) sin U(or I)	9.41777		"	
7 −log r	−1.17609		"	
8 log sin I	8.24168		"	8.71880n
9 +log N/N′	−0.18184		"	−0.18184
10 log sin I′	8.05984		"	8.90064n
11 +log r	+1.17609		"	
12 log r sin I′	9.23593		9.23593	
13 −log sin U′	−8.76567		−8.76574	
14 log (L′−r)	0.47026		0.47019	
15 U	3°00′00″	3°20′32″	.05834	
16 +I	+0 59 59		+.01745	
17 U+I	3 59 59		.06979	
18 −I′	0 39 27		−.01148	
19 U′	3 20 32		.05831	
20 L′−r	2.953		2.953	
21 +r	+15.000		+15.000	
22 L′	17.953		17.953	13.134
23 −d	−.250		−.250	−.250
24 L_1	17.703		17.703	12.884
25 log L				1.30103
26 +log tan U				+8.71940
27 log L tan U				0.02043
28 −log tan U′				−8.90303
29 log L′				1.11640

* Col. 4 will be discussed later.

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tract log N′, but in so many cases we shall be dealing with air-to-glass surfaces, where either N or N′ is 1.000 and its logarithm zero, that we adopt the convenient form N/N′. When the ray passes *into a denser medium*, the log is subtracted; when the ray passes *out of a denser medium*, the log is added. Line 10 then gives us log sin I′, completing equation (2). We look up the value of angle I′ and enter it in the angle register on line 18, and complete equation (3) on line 19. We look up log sin U′ and enter it on line 13. Line 14 completes equation (4). We look up the antilog of line 14 and enter it on line 20, add r and obtain the final answer to equation (5) on line 22.

The computation for the next succeeding surface would be written in a column immediately to the right of the one we have just completed. The U for the new surface is the U′ for the preceding one, and we subtract from L′ the distance d between the surfaces (say .25 m/m) and obtain L_1, which is the original L for surface number 2. For illustrative purposes, in Table III we copy the data brought over from the surface number 1.

5. Paraxial Rays. A large part of our computation will be concerned with rays close to the optical axis and at small intersection angles. These rays can be treated in a particularly simple fashion. The sine of a small angle is nearly enough equal to the arc, which is measured in radians. A radian is the angle subtended by the radius laid out along the arc of the corresponding circle. There are 2π radians in a complete circle, and one radian equals approximately 57.3 degrees. The substitution of x (in radians) for sin x is valid for all angles of less than one degree. So, for our so-called "paraxial" rays, we can substitute the angles themselves for their sines in equations (1) through (5) and obtain, using lower case letters to indicate paraxial quantities:[1]

$$i = \frac{(l - r)}{r} u \qquad (1p)$$

$$i' = \frac{N}{N'} i \qquad (2p)$$

$$u' = u + i - i' \qquad (3p)$$

$$l' - r = \frac{r\, i'}{u'} \qquad (4p)$$

$$l' = (l' - r) + r \qquad (5p)$$

In our logarithmic calculations, the only change necessary is that we look up the log sines under the logarithms of the natural numbers instead of under trigonometric functions, and in the angle register we shall show the natural numbers instead of degrees, minutes, and seconds. The calculation is shown in the third column of Table III. Note that the computation is identical with that for the marginal ray through line 12, if we make l = L and u = U. This is true, of course, only for the first surface, but it is convenient to save this amount of computation.

It is easy to verify, from the paraxial equations, that the final l′ is independent of the original u. We can, therefore, use the same u as for the marginal ray, and the third column of Table III is left blank as far as line 12. In the example, the difference l′—L′ shows up only in the fourth decimal place, which we are not using, but in entering the original quantities in the columns for the second surface, we use the logs as shown in the Table, as indicated, and do not look up new logs for the quantities derived after rounding off the figures. Of course, u and U for the second surface are slightly different than for the first surface.

(Next installment in December)

[1] Mathematically, these equations represent the limiting cases, and the resulting l′ is the l′ which is approached as u approaches zero.

RELATIVITY

(Continued from page 11)

dependent of the mass. This means that a mass in the field of gravity behaves as if it were not subjected to a force but only to inertia. Furthermore, since the mass does not move in a straight line with constant speed (a projectile follows a parabolic path), it behaves like a body following the law of inertia relative to a system which is *not* an inertial system (which has, for example, an acceleration relative to the fixed stars).

It is important to note that Newton reached this result by two hypotheses which cancelled each other in the result. He assumed first that the attracting force is proportional to the attracted mass *m*, and second that the acceleration is inversely proportional to this same mass. In this way he obtained for the acceleration its independency of the mass.

For two centuries, the whole period between Newton and Einstein, this fact, the proportionality of mass and gravity, was regarded as a remarkable coincidence, and finally came to be taken so much as a matter of course that it was no longer discussed at all.

But during this time, quite a few shortcomings in Newton's theory of gravitation have been revealed. Ingenious physicists, mathematicians, and astronomers have made attempts to replace Newton's theory by a more general one. It is obvious that every generalization has to begin with a hypothesis as to what part of the old theory is essential and has to be preserved and what features have to be dropped.

Generally, the essential point in Newton's theory has been believed to be the law of attraction according to which the force of gravity (value of *g*) is inversely proportional to some power of the distance *r*. Some tried to improve this power law slightly by replacing Newton's number 2 by another number (slightly more or less). Other scientists regarded the hypothesis of an action at a distance, which Newtonian gravity implies, as unessential, and assumed a general *propagation* of energy retaining the number 2.

Einstein was the first to advance the hypothesis that one essential point in Newton's theory was the proportionality between gravity and mass, which implied the cancellation of the mass *m* from the equation of motion in the gravitational field. This proportionality accounted for the fact that the separation of the geometrical and dynamical components of motion was not feasible in the case of gravity. Therefore, Einstein's starting point was the proposal that every generalization of Newton's theory had to preserve just this feature, as we shall see in our next installment.

(To be continued)

A Summary of the First Installment

NEWTON'S laws of motion are correctly considered in terms of acceleration and mass. Lack of acceleration is shown by constant speed in a constant direction. Newton's basic principle is that acceleration is inversely proportional to mass, with "force" a proportionality factor: as the mass increases, the acceleration becomes smaller in a constant field of force.

If the force is zero or the mass infinite, the acceleration is zero. This means, the motion is rectilinear with constant speed. The geometrical form of the orbit is independent of the value of the mass (provided the mass is sufficiently great).

This *geometrical* path of an infinite mass is a straight line and of uniform speed only if referred to a certain system of reference, which is called the *inertial* system. This system is in a first approximation the system of the fixed stars. In some other system, the geometrical path may appear curved, or it may appear that the mass has an acceleration. (This thought is directly applied to gravity by Einstein, but not by Newton.)

But when "forces" act on a mass which is not infinite, a dynamical component is added to its geometrical motion. In an inertial system, this is easily distinguished because it is either curved or non-uniform, whereas the geometrical component is neither. But in any other system of reference, the distinguishing becomes more difficult, and must be done by varying the mass, to see how its acceleration changes. Increasing the mass to infinity will make its motion purely geometrical.

Galileo had looked for the dynamical component in falling bodies, by changing their masses, but he obtained the peculiar result that the acceleration of a falling body is 32 feet per second each second regardless of its mass. This did not fit well with the ideas of the relation of mass and acceleration, for if a *constant* force were acting on the masses, the heavy ones should be accelerated more slowly, and take longer to fall from a given height.

Newton accounted for this apparent disagreement by assuming that the force of gravity must be variable—that it must increase with the mass, and so massive bodies, pulled down by a greater force, fell as fast as light ones. Then the disagreement disappeared in "equating the equations."

Einstein regarded this "inseparability" of the inertial and dynamical components as the essential feature of the gravitational motion. How he started his new theory from this basis we shall see in the next installment.

OBSERVER'S PAGE

All times mentioned on the Observer's Page are Eastern war time.

The Hyades Occultations and the Moon's Motion

THE moon will travel along the southern side of the Hyades during the night of October 26-27th, and at our local station we may observe, weather permitting, eight occultations in 7½ hours. This condition will hold only in the eastern United States, because the first occultation will happen when the moon is rising and so cannot be seen much farther west. In the Mississippi valley seven occultations may be seen in six hours, but in the Far West only the last two will be observed. These will appear to pass behind the northern hemisphere of the moon, instead of the southern as observed in the East.

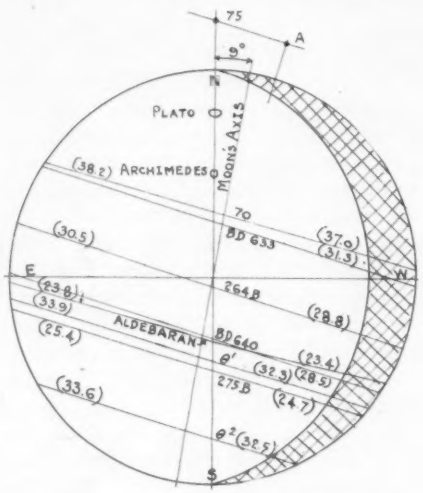
From the occultation of 70 Tauri, by the rising moon, to that of Aldebaran when it is almost on our local meridian, we may easily observe the distinct variations of the moon's *apparent speed* as it occults each of the eight stars. The amateur, with the aid of a watch and a telescope, can record these variations for himself.

The true speed of the moon is not to be confused with its apparent speed. As October 26th is three days before the moon reaches apogee (farthest from the earth), at which position it moves slowest, its true speed will be reduced gradually during the occultations. This retardation is very slight, amounting to only 3.9 miles per hour in the 7½ hours, and could not possibly be measured without special apparatus and instruments of precision. But the apparent speed decreases by 888.6 miles per hour during this same period.

The apparent speed of the moon is determined by the rotational speed of the earth. Since the motion of the moon is from west to east, and the rotation of the earth is in the same direction, the difference of the two speeds is the apparent moon's speed on the celestial sphere. At our local station, Rutherfurd Observatory at Columbia University, New York City, the rotation of the earth carries us eastward 788.86 miles an hour. The average actual speed of the moon during these occultations will be 2,194.5 miles an hour, and so the difference, or about 1,405 miles per hour, should be the apparent speed. However, this is only true for the instant that both moon and star are on the observer's meridian.

When the moon is rising, our rotational motion is nearly directly toward it (as a tangent to the earth's surface at our station will intersect the horizon and it is along this tangent that our rotational motion is taking place). Therefore, the rotational motion will not materially affect the actual speed of the moon, and its apparent speed will be about 2,194.5 miles an hour during the occultations just after moonrise; in fact, this will not change much for a couple of hours. As the moon gets higher in the sky, however, our rotational motion will enable us to keep up with it better, and the speed with which it occults a star will get less and less. The occultation of Aldebaran will require 61 per cent more time than that of 70 Tauri, although the path of the moon over each star is about equal to the other.

The diagram shows this effect for the eight cases on the 26th, and on the path of each star behind the moon I have indicated in parentheses the average speed in *miles per minute* for that part of each occultation between immersion or emersion and conjunction of the star with the moon's north-south axis. The list of occultations on the facing page shows the duration of 70, 264 B, and Aldebaran, to be 54.5, 72.8, and 87.8 minutes, respectively. Based on the moon's diameter of 2,160 miles, the actual lengths of the paths traversed during those times are 2,121, 2,159, and 2,073 miles. In this same way, the amateur can determine the moon's apparent speed during any occultation given in our monthly table by drawing a circle on a scale to represent 2,160 miles, scaling the distances between the *P*



locations on the circumference, and dividing by the elapsed time.

A very close examination of the figures on the diagram will show the speed of 70 Tauri to be greater than the actual speed of the moon. This paradox is due to an apparent westerly motion before the easterly motion begins, but the explanation is a little beyond the scope of this article. Also, the Aldebaran occultation path is not parallel to the others because it changes from *negative* to *positive* about midway; west of Philadelphia all the occultations will remain negative throughout.

Perhaps this variation in the moon's apparent speed from horizon to meridian explains better than anything else why the times of occultations are so different at different places on the earth, even though they may be relatively near each other. My own telescope is 11.75 miles northeast of our local station. I expect to see the first of the eight immersions five seconds later than the time given in our list, and, due to the slowing up of the moon's apparent speed, the last of the eight will be 30 seconds late.

Following the immersion of θ² Tauri, the star 75 Tauri, magnitude 5.3, will be in conjunction with the moon at 10:12 p.m. It will be north of the moon's edge a distance equal to 12 per cent of the moon's diameter. After the conjunction, and at position *A* on the diagram, this separation will be reduced to nine per cent.

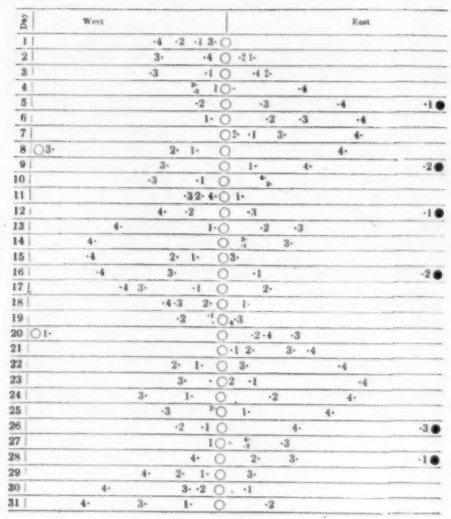
By Jesse A. Fitzpatrick

JUPITER'S SATELLITES

On October 1st, the four bright moons will be west of Jupiter after 3:13 a.m. On the 7th, they will be on the east side; and also on the 20th, prior to 3:54 a.m. After 3:17 a.m. on the 21st, they will again be on the east side and in numerical order. On the 27th, they will be on the east side prior to 5:46 a.m.

On October 2nd, a close conjunction of Jupiter with the star BD +21° 1661, magnitude 8.2, takes place at 12:16 p.m., during the day. This is unfortunate, because the separation of 19″.3 from the planet's center will bring the star within 3″ of Jupiter's southern edge. However, it does afford an opportunity for a precise study of the planet's motion, for on the 2nd at 3:00 a.m., the star will be 2′ 55″ east of Jupiter; 24 hours later it will be 4′ 52″ to the west, making a total progressive motion of 7′ 47″, about one fourth the apparent width of our moon!

Jupiter's four bright moons have the positions shown below at 3:30 a.m., E.W.T. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. From the **American Ephemeris.**



PHASES OF THE MOON

Last quarter .....October 2, 6:27 a.m.
New moon .....October 10, 0:06 a.m.
First quarter .....October 16, 6:58 p.m.
Full moon .....October 24, 0:05 a.m.

MINIMA OF ALGOL

October 4, 3:43 a.m.; 7, 0:32 a.m.; 24,5:24 a.m.; 27, 2:13 a.m.; 29, 11:02 p.m.

Answers to DO YOU KNOW?

(Questions on page 5)

I. 1, a; 2, b; 3, a; 4, c; 5, b; 6, c; 7, d; 8, b; 9, b; 10, d.

II. 1, declination; 2, Jupiter; 3, wave length; 4, Capricornus; 5, luminosity or brightness; 6, opposition or elongation; 7, Jupiter; 8, Castor; 9, Thuban (αDraconis); 10, Venus.

OCCULTATIONS—OCTOBER, 1942

Local station, lat. 40° 48′.6, long. 4^h 55.8^m west.

Date	Mag.	Name	Immersion	P.*	Emersion	P.*
Oct. 26	6.4	70 Tauri	8:22.5 p.m.	57°	9:17.0 p.m.	272°
26	4.0	θ^1 Tauri	9:43.3 p.m.	96°	10:43.5 p.m.	231°
26	3.6	θ^2 Tauri	9:50.8 p.m.	122°	10:33.8 p.m.	205°
26	6.6	BD +15° 633	....	58°	11:06 p.m.	268°
26	4.8	264 B Tauri	10:48.5 p.m.	75°	0:01.3 a.m. (27)	250°
26	6.7	BD +15° 640	....	89°	0:05.4 a.m. (27)	236°
27	6.5	275 B Tauri	0:42.5 a.m.	99°	1:59.6 a.m.	228°
27	1.1	Aldebaran	2:19.0 a.m.	92°	3:46.8 a.m.	239°
28	5.3	115 Tauri	2:48.7 a.m.	109°	4:09.8 a.m.	231°
29	6.2	19 B Geminorum	0:10.7 a.m.	56°	1:17.9 a.m.	287°
31	5.8	3 Cancri	4:19.3 a.m.	97°	5:51.8 a.m.	278°

* P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

THE PLANETS IN OCTOBER

Mercury will be at greatest western elongation, 18° 28′, on October 26th. The position of the planet, 9° north of the sun, and its stellar magnitude of 0.8 will make it visible shortly before sunrise.

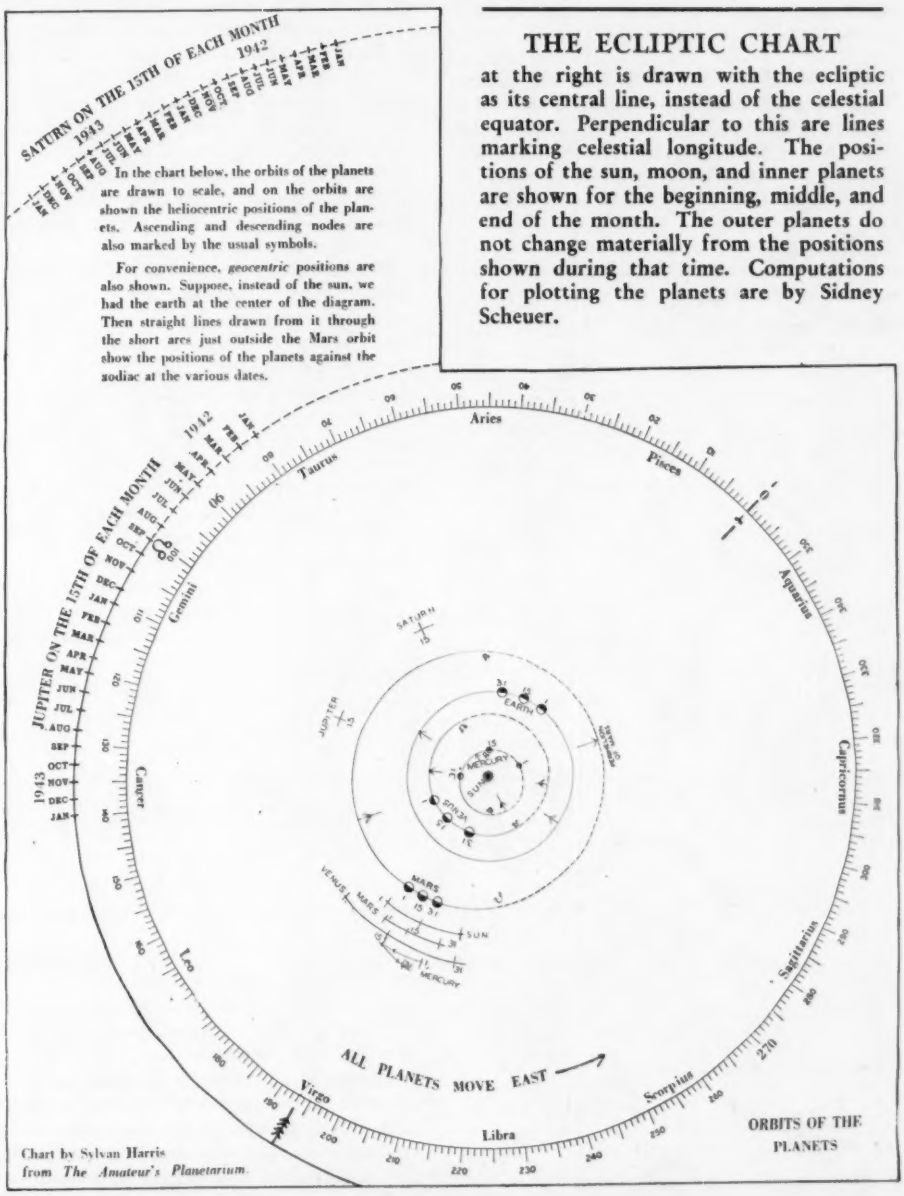
Venus and *Mars* are too near the sun for observation.

Vesta, brightest of the minor planets, will be well placed for observation with binoculars. On October 1st, it will be 8° southwest of the group of three double stars, o, π, and ϱ Capricorni, 1½° northeast of 355 B Capricorni, and 7° west of ψ Capricorni. Its motion will be toward the latter star, and its magnitude of 6.9 will hold during the early part of the month.

Jupiter is in a dense part of the Milky Way, in Gemini.

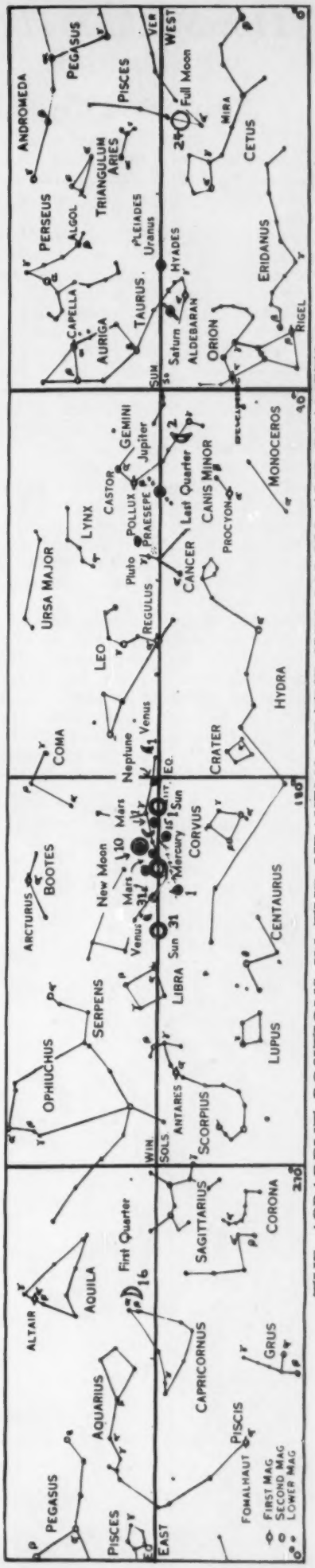
Saturn and *Uranus* are in Taurus, near the Pleiades.

Neptune, in Virgo, will be far enough from the sun for observation at the end of the month.


SATURN ON THE 15TH OF EACH MONTH
1942
1943
In the chart below, the orbits of the planets are drawn to scale, and on the orbits are shown the heliocentric positions of the planets. Ascending and descending nodes are also marked by the usual symbols.
For convenience, geocentric positions are also shown. Suppose, instead of the sun, we had the earth at the center of the diagram. Then straight lines drawn from it through the short arcs just outside the Mars orbit show the positions of the planets against the zodiac at the various dates.
JUPITER ON THE 15TH OF EACH MONTH
1942
1943
Aries
Taurus
Gemini
Cancer
Leo
Virgo
Libra
Scorpius
Sagittarius
Capricornus
Aquarius
Pisces
ALL PLANETS MOVE EAST
ORBITS OF THE PLANETS
Chart by Sylvan Harris
from The Amateur's Planetarium

THE ECLIPTIC CHART

at the right is drawn with the ecliptic as its central line, instead of the celestial equator. Perpendicular to this are lines marking celestial longitude. The positions of the sun, moon, and inner planets are shown for the beginning, middle, and end of the month. The outer planets do not change materially from the positions shown during that time. Computations for plotting the planets are by Sidney Scheuer.



THE APPARENT POSITIONS IN THE HEAVENS OF THE SUN, MOON, AND PLANETS.

THE STARRY HEAVENS IN OCTOBER

By Leland S. Copeland

Nubia's Shining Trio and the Fighting Flier from Greece

WERE three constellations of October named in honor of negroes? So Milton suggests when he calls Cassiopeia black. But in poetry *black* is ambiguous; it might mean *brunette*.

Cepheus was king of Ethiopia, yet where was Ethiopia? To Homer it was somewhere at the world's end. Later the word referred to Nubia, the Sudan, and Abyssinia. Probably Cepheus ruled Nubia, between the first and fourth cataracts of the Nile, and Andromeda was chained beside the Red Sea. In this region, wrote Herodotus, lived men with straight, as well as kinky, hair. So we may conclude that Andromeda was white, as artists have depicted her, though mythology is not exact, as is science.

Luckless was any earthly woman who remarked, "I'm as handsome as the immortals." Queen Cassiopeia, making that mistake, angered the sea nymphs. An oracle said that as punishment her daughter must be sacrificed to a sea monster. Unable to resist, Cepheus ordered that Andromeda should be fettered to a rocky cliff.

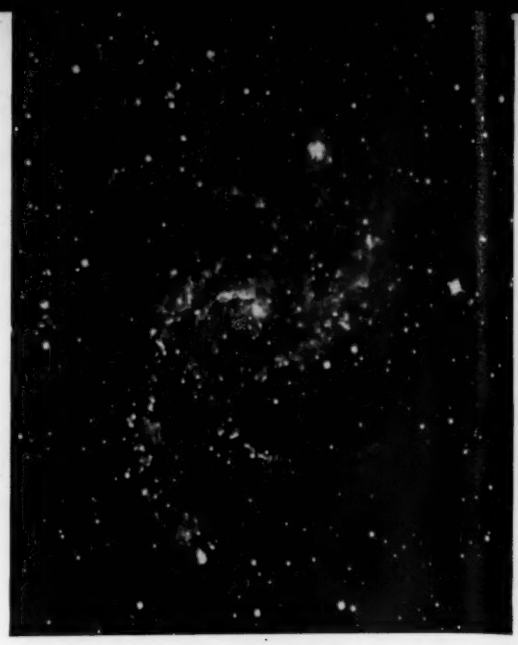
Before the great beast, represented nowadays by starry Cetus, could harm the princess, out of the sky came Perseus. This fearless youth, born in Argos, had become an aviator by borrowing Mercury's "sandal shoon." First he slew the snaky-haired Gorgon; then, by displaying Medusa's head, he turned inhospitable Atlas into a stone mountain. As the Greek hero, like Richard Halliburton, went flitting round the world, he spied the girl in chains and fell in love with her. Against such an agile flier the sea monster had no more chance than the Nips at Midway.

A wedding feast followed. When Phineas, Andromeda's former fiancé, and his companions tried to steal the bride, Perseus with Medusa's head turned the uninvited guests into statuary. Then the wedded pair sailed to Argos, where the hero became king. Hercules was their grandson.

Starry memorials to the Nubians and their deliverer beautify the northern and northeastern sky of October nights.

Cassiopeia is represented by a choice constellation, the chair or great W, at the end of a line from the handle of the Big Dipper through the North Star. Besides doubles α, ι, η, she is jeweled with at least six important clusters, including M52, halfway between the chair and Perseus; and the especially beautiful N.G.C. 7789, south of β.

Cepheus, resembling a church steeple, with the point toward Polaris, is less resplendent. But he also has attractions for amateur telescopes, including μ, Herschel's garnet star; δ, a yellow and blue double, first of the Cepheids, by which astronomers measure remote distances; and N.G.C. 6946, four-armed spiral, possible member of the galactic cluster containing our own Milky Way system. N.G.C. 6946 (galaxy pictured on this page) can be glimpsed with difficulty through a large amateur telescope ($20^h\ 33^m.9$, $+59°\ 58'$). It is close to a dim cluster.



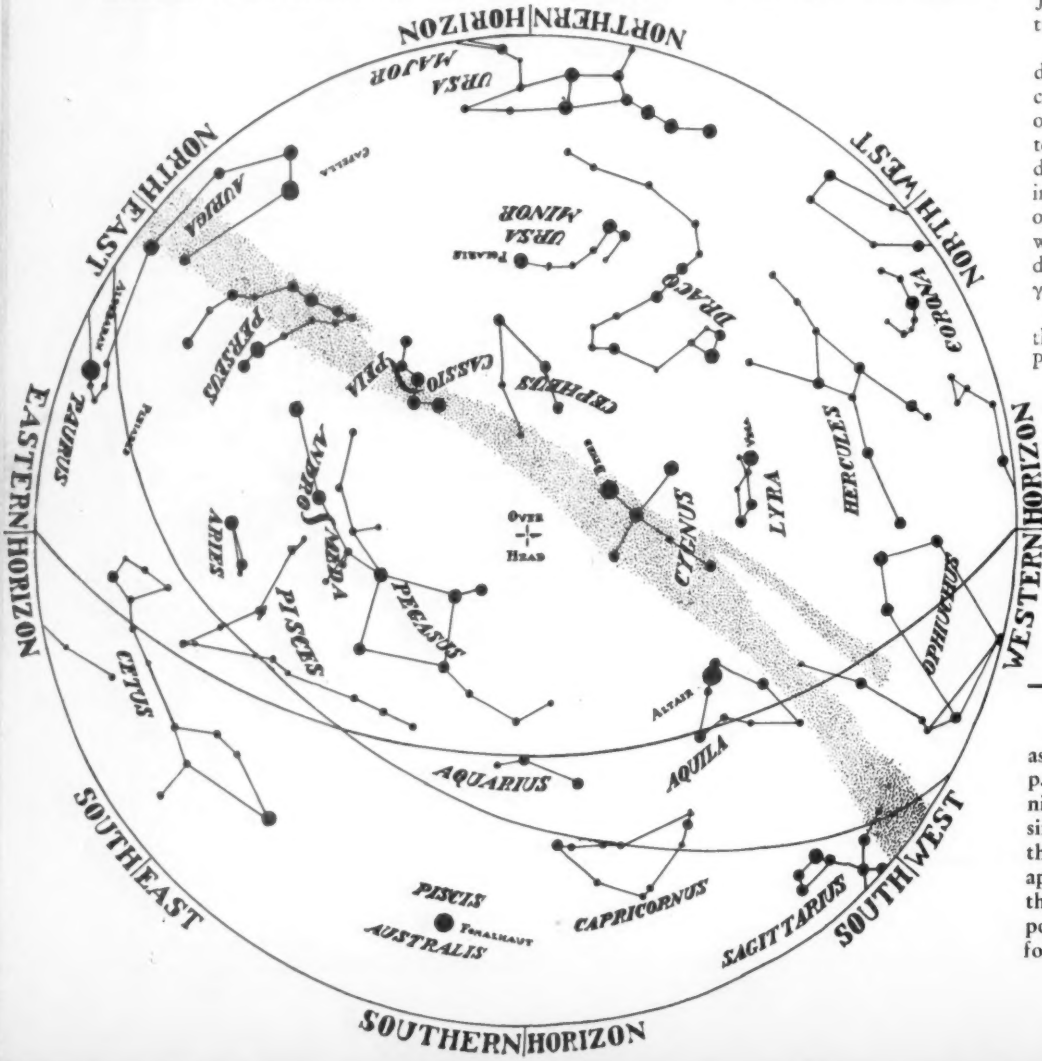
The four-armed spiral, N.G.C. 6946, photographed at Mt. Wilson Observatory.

Andromeda's head rests on Pegasus, with which she shares Alpheratz, and her feet are at γ, a handsome double, orange and blue. "Outstretched forever are those hands of hers," writes Aratos. Her southern arm reaches down to one of the Fishes. The bright Y-shaped northern hand, once called Gloria Frederika, is a pleasing detail. Unaided vision can glimpse, near ν, the great spiral, M31, and a telescope shows its small elliptical companions, M32 and N.G.C. 205. Just east of γ is N.G.C. 891, a much-pictured edge-on galaxy.

Perseus more nearly resembles an airy dancer than a hard-hitting fighter. This constellation consists of three curved lines, one facing Andromeda, another concave toward the northeast, and a third sliding down to the Pleiades. Remarkable features include the double cluster, hχ, behind Cassiopeia's chair; Algol (β), the Demon Star, winking through a period of nearly three days; M34, open cluster, between Algol and γ Andromedae.

At 10 p.m. war time, in mid-October, the meridian passes through Cepheus, crosses Pegasus and Aquarius, and descends just west of Fomalhaut. Aries and Taurus sparkle in the east, and Cetus stretches his great frame across the southeast.

Sinking in the west are Corona Borealis, Ophiuchus, and Sagittarius. They are followed by inverted Hercules, wide-winged Aquila with white Altair, and little Lyra with great Vega, brightest star in the Northern Hemisphere. High in the west, Cygnus and Delphinus close the recession of the beloved constellations of summer.



THE STARS FOR OCTOBER

as seen from mid-northern latitudes at 10 p.m., Oct. 7th; 9 p.m., Oct. 23rd. Magnitudes of the stars are indicated by the sizes of the disks marking the stars, and the names of some of the brighter stars appear. The ecliptic and equator are shown, the latter touching the east-west horizon points. See chart on the "Observer's Page" for sun, moon, and planet positions.

THE list of double stars in the adjoining columns is the third in a series which will cover the entire sky, furnishing amateurs with complete observing data on bright, resolvable binaries. See the "Observer's Page" in the issues of June and July, 1942, for an article on the visual observation of double stars. Previous lists appeared in June and August; the next will appear in December, covering 0h to 4h.

The columns are: star designation; right ascension, declination (1950); photometric magnitudes; "Aitken" visual magnitudes; spectral classes; separation; position angle.

A and *B* are the brighter (primary) star and fainter star, respectively. Where available, the photometric magnitudes are given to two places; magnitudes in parentheses are estimated or uncertain. "Aitken" magnitudes are from visual observations and often differ greatly from the photometric figures, therefore the former are useful chiefly to indicate the relative magnitude difference between the components.

The data for this table is compiled from the Boss *General Catalogue;* Aitken's *Double Star Catalogue;* and Innes' *Southern Double Stars.*

LIST OF DOUBLE STARS—R. A. 20h to 24h

	Star	*R. A.* h	m	*Dec.* °	′	*Photometric mag.* A+B	A	B	*Aitken* mag.	*Spectra* A	B	*Sep.* ″	*P.A.* °
Aquarius	12	21	1.4	— 6	1	(5.6)	5.89	7.31	5 6—7.7	F5	A3	2 8	192
	41	22	11.5	—21	19	5.45	.....	.....	5.7—7.7	G5	....	5.0	115
	53	22	23.9	—17	0	(5.7)	6.35	6.57	6.3—6.6	G0	G0	5.5	313
	ζ	22	26.3	— 0	17	(3.7)	4.42	4.59	4.4—4.6	F2	F2	2.9	283
	94	23	16.5	—13	44	.....	5.27	(7.3)	5 2—7 2	G5	....	13.3	348
	107	23	43.4	—18	57	5.45	(5.7)	(7.0)	5 3—6.5	A5	A5	6.3	136
Capricornus	π	20	24.5	—18	23	5.20	.....	.....	5.1—8.7	B8	....	3.4	145
	ϱ	20	26.0	—17	59	4.96	.....	.....	5.0–10.0	F0	....	2.2	168
	o	20	27.0	—18	45	(5.6)	6.10	6.64	6.1—6.6	A2	A3	21.9	238
Cassiopeia	σ	23	56.5	+55	29	4.93	.....	(7.0)	5.4—7.5	B2	....	3.1	326
Cepheus	ϰ	20	10.6	+77	34	4.40	.....	.....	4 0—8.0	B9	....	7.4	122
	β	21	28.0	+70	20	3.32	.....	.....	3.3—8.0	B1	....	13.6	250
	13H	21	38.8	+57	21	7.08	.....	(8.1)	7.5—8.5	F5	....	12.7	58
	ξ	22	2.3	+64	23	(4.4)	4.57	6.47	4.6—6 5	A3	G	7 4	281
	o	23	16.6	+67	50	4.90	.....	.....	5.2—7.8	G5	....	3 0	205
Cygnus	49	20	39.0	+32	8	5.77	(5.9)	.....	6.0—8.1	G7	....	2.8	46
	59	20	58.1	+47	19	4.86	.....	(9.3)	4.7—9.0	B0p	....	20.3	352
	61	21	4.7	+38	30	(5.1)	5.57	6.28	5.6—6.3	K5	K6	25.0	140
	τ	21	12.8	+37	50	3.82	.....	.....	3.8—8.0	F0	....	(0.9)	(120)
Delphinus	γ	20	44.3	+15	57	(4.1)	4.49	5.47	4.0—5 0	G5	F8	10 5	270
Equuleus	λ	20	59.7	+ 6	59	6.64	(7.4)	(7.4)	7.1—7.1	F8	....	2 8	220
Lacerta	8	22	33.6	+39	22	(4.1)	5.83	6.55	6.0—6.5	B3p	B5	22.3	186
Pegasus	1	21	19.8	+19	35	4.24	.....	.....	4.5—8 6	K0	K5	36.3	311
Piscis Austrinus	β	22	28.7	—32	36	4.36	.....	.....	4.5—7.5	A0	....	30.0	170
	γ	22	49.8	—33	8	4.52	....	(8.5)	4.6—8.8	A0	....	4.3	267

PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents *in October,* MODERN SKY PICTURES—by Cy Hungerford.

In this new and different sky show, the famous cartoonist, Cy Hungerford, turns his unique talent for humorous and trenchant characterization to the heavens, revamping the star pictures of the ancients and presenting them in modern dress. Have you found it difficult to see in the stars of Cetus the figure of a sea-monster? Or a winged horse in the stars of Pegasus, or a queen in the W of Cassiopeia? Has it been easier for you to imagine in the starry heavens other objects more familiar to us in the streamlined world of 1942?

Why not, then, transfer the great changes that have taken place below to the heavens above? Certain evidence indicates that the original constellation pictures may have had woven in them some ancient legend—a story immortalized in the stars. In this sky show, we see how the stars can tell us some new story, woven about our modern things and people by one of America's great cartoonists.

★ **THE HAYDEN PLANETARIUM** presents *in October and November,* SAILING THE SEVEN SEAS. *(See page 6.)*

Here the Hayden Planetarium will present a colorful pageant of the development of navigation. From ancient days to the present, man has constantly sought new methods for finding his way over the earth. The early Polynesians, the Columbus age of explorers, the windjammer, the modern flying fortress—each had its own techniques. By means of complicated projection, music, and newly-created effects, the story will be unfolded on the Planetarium sky. Nor will the principles of navigation be neglected in this popular story.

New classes in Navigation and Star Identification start November 5th. Each course consists of 10 lectures in the dome of the Planetarium on Tuesdays and Thursdays for five weeks. The fee for each course is $2.50; write to the Hayden Planetarium for an application blank and further information.

★ SCHEDULE BUHL PLANETARIUM

Tuesdays through Fridays.....3 and 8:30 p.m.
Saturdays .....2, 3, and 8:30 p.m.
Sundays and Holidays.....3, 4, and 8:30 p.m.
(Building closed Mondays)

★ STAFF—*Director,* Arthur L. Draper; *Lecturer,* Nicholas E. Wagman; *Business Manager,* Frank S. McGary; *Public Relations,* John J. Grove; *Curator of Exhibits,* Fitz-Hugh Marshall, Jr.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays.....2, 3:30, and 8:30 p.m.
Saturdays .....11 a.m., 2, 3, 4, 5, and 8:30 p.m.
Sundays—Mutual Network Broadcast—Coast-to-Coast..9:30–10 a.m.
Sundays and Holidays.....2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator,* Clyde Fisher; *Curator,* William H. Barton, Jr.; *Assistant Curators,* Marian Lockwood, Robert R. Coles (on leave in Army Air Corps), John Ball, Jr.; *Staff Assistant,* Fred Raiser; *Lecturers,* Asa Tenney, Charles H. Coles.